Nutrient, Sediment, and Dissolved Oxygen TMDLs for Blacktail Dam in Williams County, North Dakota

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Blacktail Dam is located in Williams County, North Dakota, 18.5 miles north and 5 miles west of Williston, North Dakota in the northwest corner of the State (Figure 1). The reservoir was created by damming Blacktail Creek, a tributary of the Little Muddy River. Wildlife habitat and recreation opportunities were the intent of the reservoir's construction. Currently there are approximately 119seasonal cabins and permanent residences situated around the reservoir. The contributing watershed of Blacktail dam is 27 square miles (mi^2), containing a 43 mile network of streams with two main tributaries. Blacktail Creek is the northern most tributary draining 85 percent of the watershed, while the south tributary is unnamed and drains the remaining 15 percent of the watershed. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Blacktail Dam and its watershed.

Table 1. General Characteristics of Blacktail Dam and its Watershed.

Legal Name	Blacktail Dam
Major Drainage Basin	Missouri River
Nearest Municipality	Williston, ND
Assessment Unit ID	ND-10110102-003-L_00
County Location	Williams County, ND
Physiographic Region	Glaciated Dark Brown Prairie
Latitude	48˚25'47"
Longitude	-103˚43'58"
Surface Area	146.9 – acres
Watershed Area	17,482 – acres
Average Depth	16.4 – feet
Maximum Depth	38.5 – feet
Volume	2,412.7 - acre-feet
Tributaries	Blacktail Creek, Unnamed Tributary
Type of Waterbody	Constructed Reservoir
Fishery Type	Walleye, Smallmouth Bass, Northern Pike

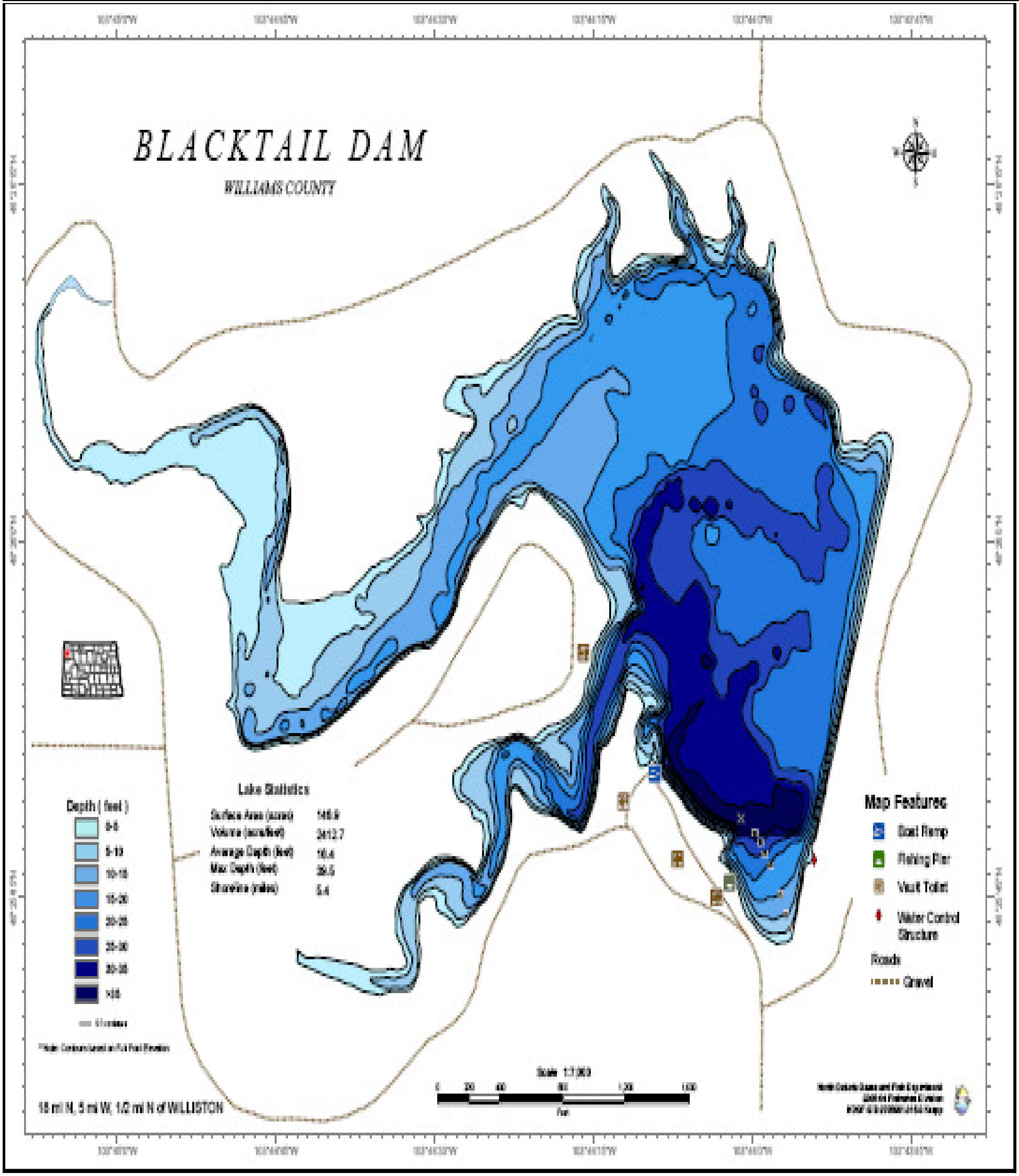


Figure 1. North Dakota Game and Fish Contour Map of Blacktail Dam.

1.1 Clean Water Act Section 303(d) Listing Information

Based on the 2006 Section 303(d) list of impaired waters needing TMDLs, the North Dakota Department of Health (NDDoH) has identified Blacktail Dam as fully supporting recreation and aquatic life beneficial uses, but they are threatened as a result of eutrophication from nutrient enrichment, low dissolved oxygen concentrations, and sedimentation (ND-10110102-003-L_00) (Table 2). Fish and other aquatic biota inhabiting the reservoir are threatened because of low dissolved oxygen concentrations in the hypolimnion and accelerated eutrophication as a result of nutrient enrichment from the contributing watershed. In addition, sedimentation is threatening aquatic life and the longevity of the reservoir. The recreational uses of the reservoir are being threatened by eutrophication from nutrient enrichment.

Table 2. Blacktail Dam Section 303(d) Listing Information (NDDoH, 2006).

Waterbody Name	Blacktail Dam
Assessment Unit ID	ND-10110102-003-L_00
Class	3 – Warm water fishery
Impaired Uses	Fish and Other Aquatic Biota, Recreation; (fully supporting but threatened)
Causes	Nutrients, Sedimentation/Siltation, low dissolved oxygen
Priority	High (1A)

1.2 Topography

Blacktail Dam and its watershed lie within the Glaciated Dark Brown Prairie level IV ecoregion (42i). This ecoregion has a well defined drainage system and fewer wetlands compared to the Missouri Coteau Slope which lies to the east of Blacktail Dam and the Dark Brown Prairie ecoregion. The Northwestern Glaciated Plains level III ecoregion, in which Blacktail Dam resides, marks the westernmost extent of continental glaciation. Much of the land in the area is transitional between the dryland farming that dominates the land to the east (ecoregion 46i), and prevalent cattle ranching practices to the west (ecoregion 43). As a result, ecoregion 42i represents a mosaic of cropland and rangeland. The established drainage pattern present in the ecoregion consists of gently rolling plains sloping toward the Missouri River. Elevation of the area ranges between 1,950-3,000-feet (MSL), with Blacktail Dam situated at approximately 2,077-feet (MSL). Local relief is between 50-and-200-feet. Figure 2 shows the general location, shape, and size of the Blacktail Dam watershed in Williams County, North Dakota.

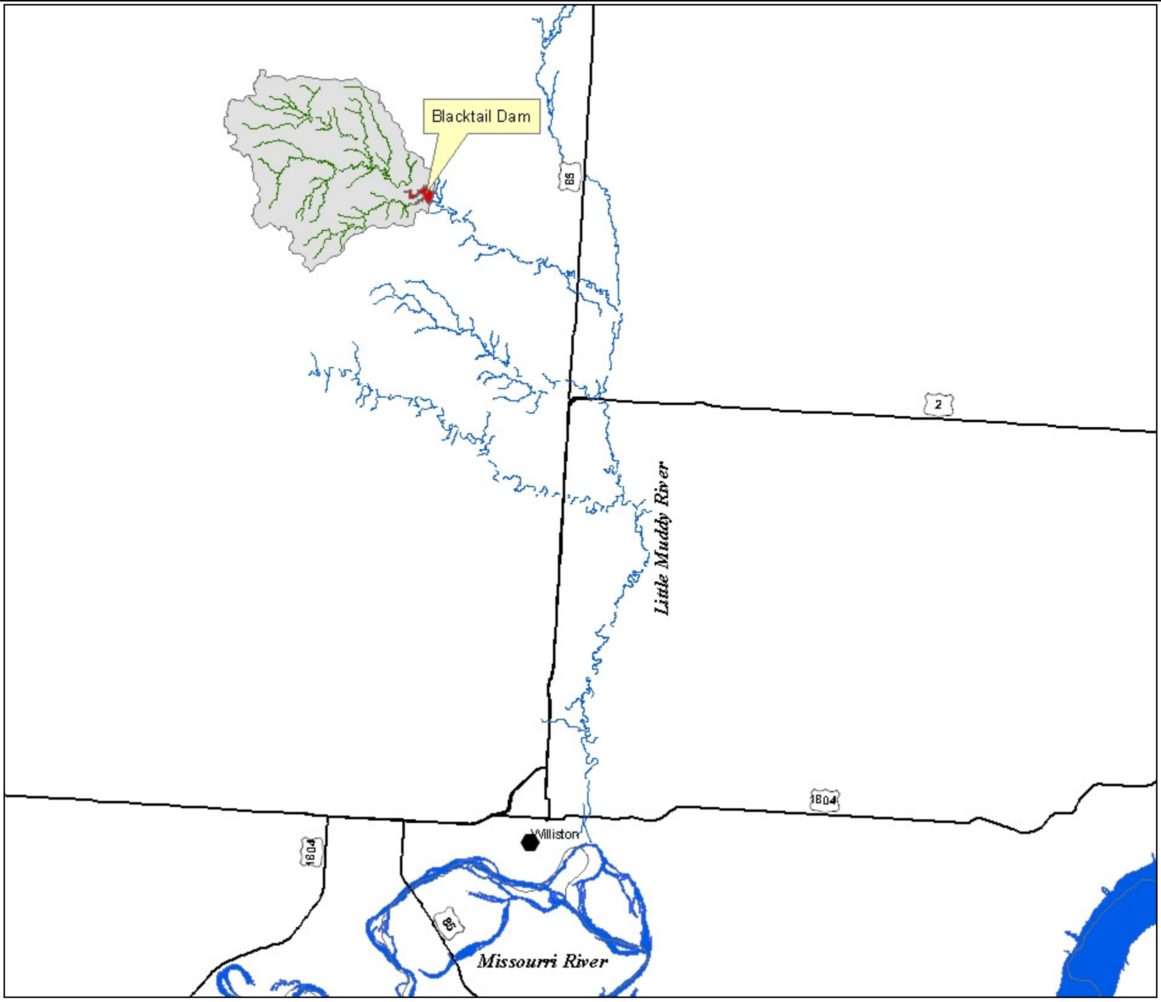


Figure 2. General Location of Blacktail Dam Watershed.

1.3 Land Use/Land Cover

Land use in the watershed is primarily agricultural (97 percent), consisting of cash crop production and livestock grazing. The land is tilled mainly for durum, spring wheat, and other small grains (Table 3). Some irrigated cropland can be found in areas near the Missouri River. Three concentrated livestock feeding operations reside in the Blacktail Dam watershed. The geology of the ecoregion is comprised of glacial till over tertiary sandstone and shale. Soil series include: Williams, Zahl, and Bowbells. Potential native vegetation in the watershed may include blue grama, needle-and-thread, western wheatgrass, green needlegrass, and little bluestem. Land use adjacent to or around the reservoir consists of approximately 119 seasonal and permanent cabins/homes.

Table 3. Land Use Estimates Within the Blacktail Dam Watershed, 2006.

Land Use Type	Acres	Percent of Total Acreage
Cropland	12,264	70
Rangeland	4,767	27
Hayland	100	<1
Conservation Reserve Program (CRP)	0	0
Urban, Farmstead	25	<1
Water	326	2

1.4 Climate and Precipitation

The climate of northwestern North Dakota and the area encompassing Blacktail Dam is semiarid to sub-humid and continental. Precipitation events are sporadic occurring primarily as rainfall in May through July where monthly rainfall is greater than two inches (Figure 3). The average snowfall is 37 inches and average rainfall is 14 inches annually. Sunshine occurs 62 percent of the time annually (Soil Survey of Williams County, USDA Soil Conservation Service, 2000). Summers are warm with frequent bouts of hot weather and sporadic cool days. On average there are between 110-130 frost free days per year in the ecoregion. Winters are cold, especially when arctic air from Canada surges over the area. The normal temperature in January is 9°F while the normal temperature in July is 70°F (NDAWN, 2005) (Figure 4). Since North Dakota Agricultural Weather Network (NDAWN) period of record data was too short to accurately calculate normal air temperatures alone, NDAWN normal air temperatures were calculated through interpolation of monthly normal air temperature measurements from nearby National Weather Service (NWS) Cooperative Stations data (1971-2000).

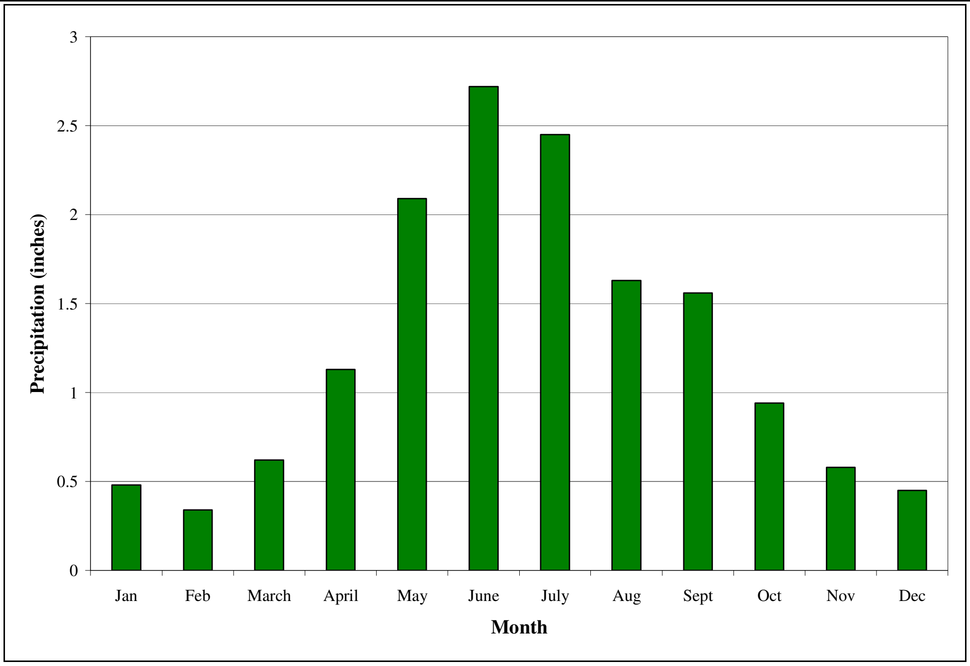


Figure 3. Normal Monthly Precipitation from 1971-2000 at the North Dakota Agriculture Weather Network (NDAWN), Williston, ND Weather Station.

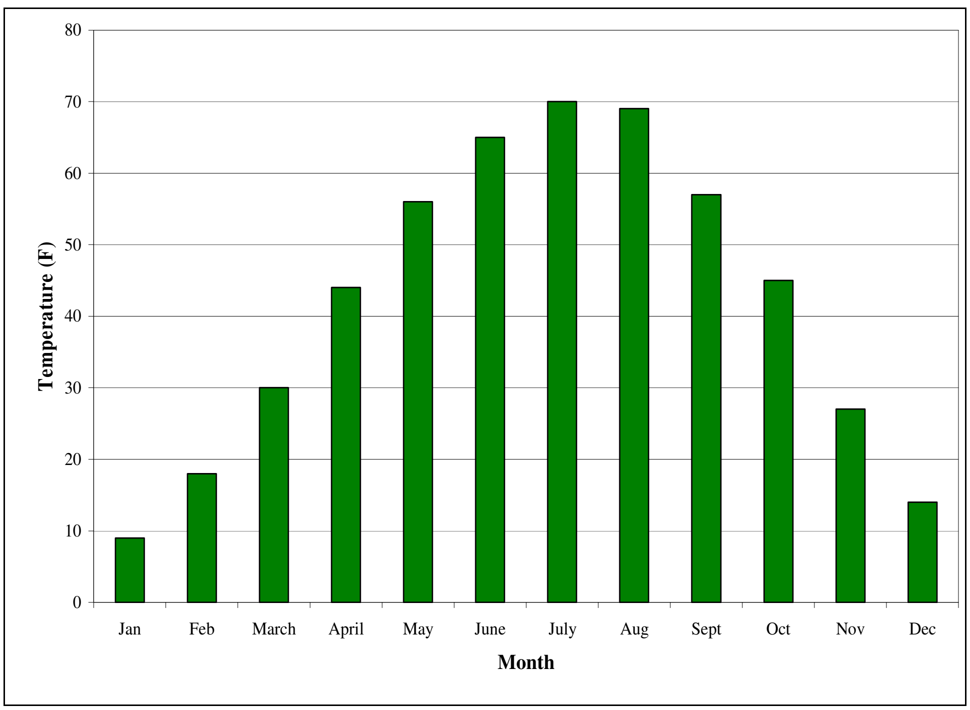


Figure 4. Normal Monthly Temperature from 1971-2000 at NDAWN, Williston, ND Weather Station.

1.5 Water Quality Data

1.5.1 1991-1992 Lake Water Quality Assessment Project

A Lake Water Quality Assessment (LWQA) was conducted on Blacktail Dam during 1991-1992. Water quality samples were taken twice during the summer of 1991 and once during the winter of 1991-1992 from the reservoir. Samples were collected from one sampling site (380540) at depths ranging from just below the surface, the middle of the water column, and near bottom depths of the dam. Stratification of Blacktail Dam was observed during both sampling periods in the summer of 1991. On July 16th, thermal stratification was observed below the thermocline at approximately six meters below the lake surface. The thermocline was observed at nine meters on August 6, 1991. Oxygen levels were less than 2 mg/L below the thermocline during both sampling periods.

The 1991-1992 LWQA characterized Blacktail Dam as having relatively high concentrations of total phosphate as P (113 µg/L). In addition, trophic status was determined using the water quality data collected during the LWQA project. Blacktail Dam was considered a highly eutrophic to hypereutrophic reservoir. Supporting data for this assessment included: total phosphate as P concentrations between 67 and 118 µg/L, chlorophyll-*a* concentrations ranging from 13-33 µg/L, and a Secchi disk transparency depth of 1.6 meters.

1.5.2 2003-2004 Blacktail Dam TMDL Development Project

Recognizing the need to improve water quality conditions in Blacktail Dam, a TMDL development project was initiated with sponsorship by the Williams County Soil Conservation District. Data for the TMDL development project was collected between June 2003 and October 2004. Water quality samples were collected at two tributary sites, one in-lake site, and one site at the outlet of the reservoir (Figure 5). General characteristics of the monitoring sites can be found in Table 4.

Table 4. General Description of Monitoring Sites.

Station ID	Station Description	Samples Collected	Latitude	Longitude
385239 (South Tributary)	17 miles N & 6 miles W of Williston	28	48.42741	-103.74836
385240 (North Tributary)	17.5 miles N & 6 miles W of Williston	29	48.43866	-103.75173
380540	Near Dam at deepest point	25	48.42984	-103.7331
385241 (Outlet)	17 miles N & 5 miles W of Williston	17	48.42989	-103.73062

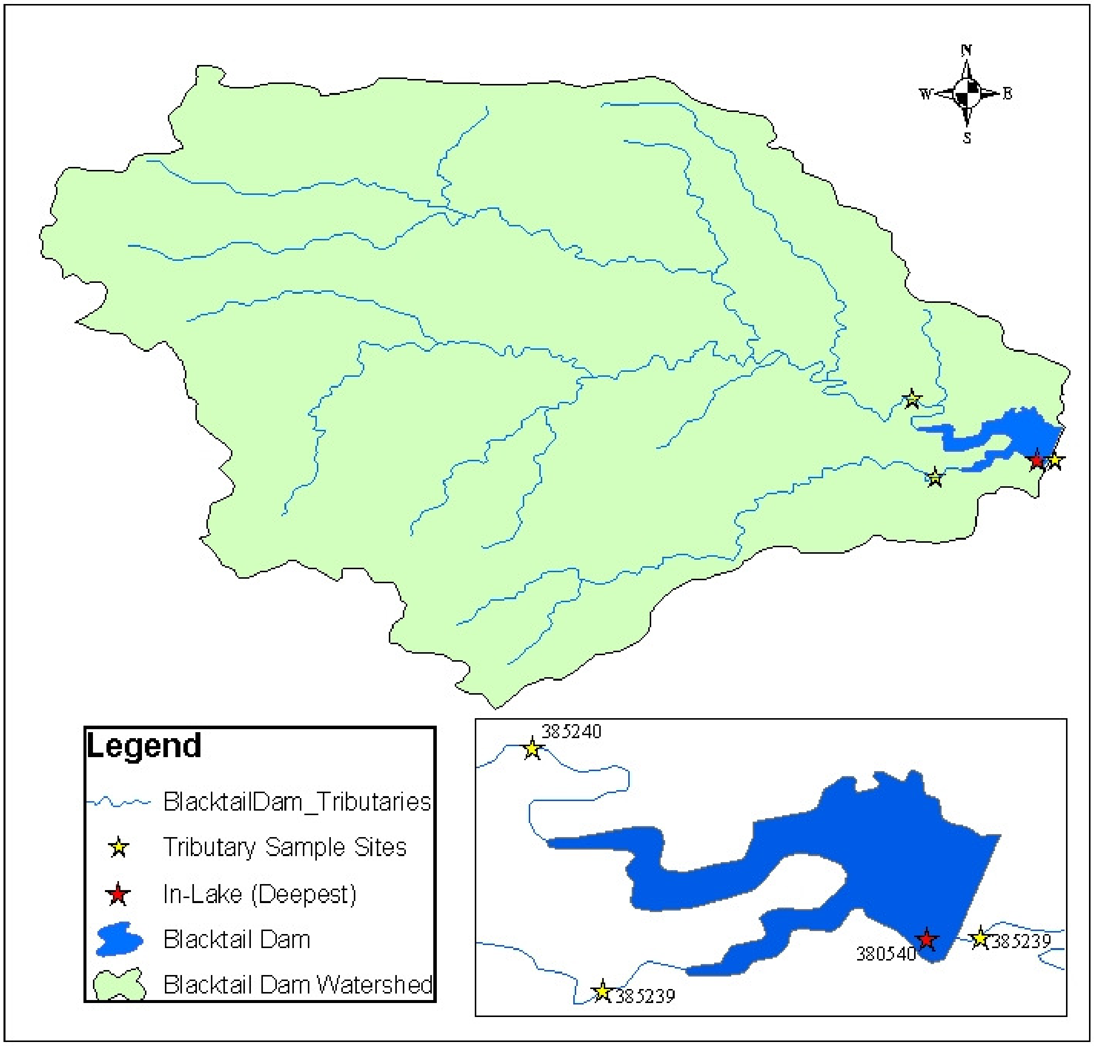


Figure 5. Monitoring Site Locations on Blacktail Dam and Its Tributaries.

<u>Stream Monitoring</u>

Sampling frequency for the stream sampling sites was stratified to coincide with the typical hydrograph for the region. This sampling design results in more frequent samples during spring and early summer when stream discharge was typically greatest. Less frequent samples were taken during late summer and fall. Sampling efforts were discontinued during winter ice cover conditions, and terminated when the stream stopped flowing. If the stream began flowing again, water quality sampling was reinitiated.

<u>Reservoir Monitoring</u>

In order to accurately account for temporal variation in lake water quality, the lake was sampled twice per month during the spring and early summer season and monthly during fall and ice cover conditions. Reservoir monitoring was conducted at depths of 0.5 meters below the surface, mid-depth, and 0.5 meters from the reservoir bottom.

Nutrient Data

Surface water quality parameters were monitored in Blacktail Dam at three sampling stations between June 2003 and October 2004. Water quality data were collected on two tributaries upstream of Blacktail Dam (385239 and 385240) and one tributary downstream (385241). A suite of nutrients and total suspended solids (TSS) were collected for analysis. Table 5 highlights general statistics of total phosphorus, total nitrogen, nitrite + nitrate as nitrogen and TSS. In addition to water quality, stream stage and discharge were measured. An automated stage recorder and staff gauge were installed at each site and discharge was measured during each water quality sampling trip. The data extracted from Blacktail Dam indicates that the reservoir is phosphorus limited with an average total nitrogen (TN) to total phosphorus (TP) ratio of 13:1.

Table 5. Summary Statistics for Water Quality Variables Sampled in Tributary Monitoring Stations 385239, 385240 and 385241.

Variable	Station ID	Number of Samples Collected	Maximum (mg/L)	Minimum (mg/L)	Mean (mg/L)	Median (mg/L)
Total Phosphorus	385239	28	0.240	0.039	0.097	0.084
	385240	29	0.181	0	0.059	0.054
	385241	17	0.823	0.012	0.162	0.079
Total Nitrogen	385239	28	1.620	0.458	0.865	0.827
	385240	29	2.050	0	0.975	0.921
	385241	17	2.580	0.759	1.254	1.210
Nitrate+Nitrite as N	385239	28	0.450	0	0.143	0.105
	385240	29	1.160	0	0.141	0.020
	385241	17	0.120	0	0.047	0.040
Total Suspended Solids	385239	27	56	0	10	0
	385240	29	48	0	4	0
	385241	17	41	0	5	0

Reservoir water quality samples were collected at one monitoring site (380540) located at the deepest point near the dam itself (Figure 5) (Table 6). Twenty-five samples were collected between June 12, 2003 and October 31, 2004 during the open water season and under ice cover. Parameters sampled and measured include: phytoplankton, chlorophyll a, pH, specific conductance, major cations and anions, total nitrogen, total Kjeldahl nitrogen, nitrate-nitrite, ammonia, phosphorus (total and dissolved), Secchi disk transparency, and temperature and dissolved oxygen profiles. A summary of the water quality data specific to this TMDL is provided in Table 6.

Table 6. Summary Statistics for Water Quality Variables Sampled in Blacktail Dam.

Variable	Units	Maximum	Minimum	Volume Weighted Mean	Median
Total Phosphorus	mg/L	1.190	0	0.078	0.048
Total Nitrogen	mg/L	3.740	0.575	1.031	0.973
Total Kjeldahl Nitrogen	mg/L	3.720	0.485	0.998	0.930
Nitrate+Nitrite as N	mg/L	0.190	0	0.034	0.020
Ammonia as N	mg/L	2.060	0	0.116	0.038
Chlorophyll-a	µg/L	66	0	15	7
Secchi Disk	Meters	6.3	1.1	2.547	2.4

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature were monitored at the deepest site and inlet site of Blacktail Dam from June 2003 through October 2004. Measurements were taken at 1-meter depth intervals during ice cover and open water periods each time a water quality sample was collected. A summary of the data is provided in Appendix A, while Figures 6 through 9 illustrate the results of the temperature and dissolved oxygen data for the in-lake monitoring site for both years, respectively. During the summer sampling of 2003, Blacktail Dam was thermally stratified on June 12th between 9 and 10-meters of depth. At that time dissolved oxygen concentrations ranged from 8.4 mg/L at the surface, to 2.0 mg/L at 9-10-meters, and 0.2 mg/L at the bottom. Based on the 2003-2004 data, there appears to be a period during the summer season (June-August) when dissolved oxygen consistently falls below the 5 mg/L state standard in the hypolimnion. Samples were only taken once during the months of August and September 2003 due to equipment malfunctions. With the exception of measurements taken near the bottom depths, (7-10-meters) and late winter month measurements, the lake site appears to consistently have dissolved oxygen levels above the state standard. The cause-and-effect relationship between nutrients, water temperature, plant growth and decomposition, and low dissolved oxygen levels in a waterbody is well established in the scientific arena.

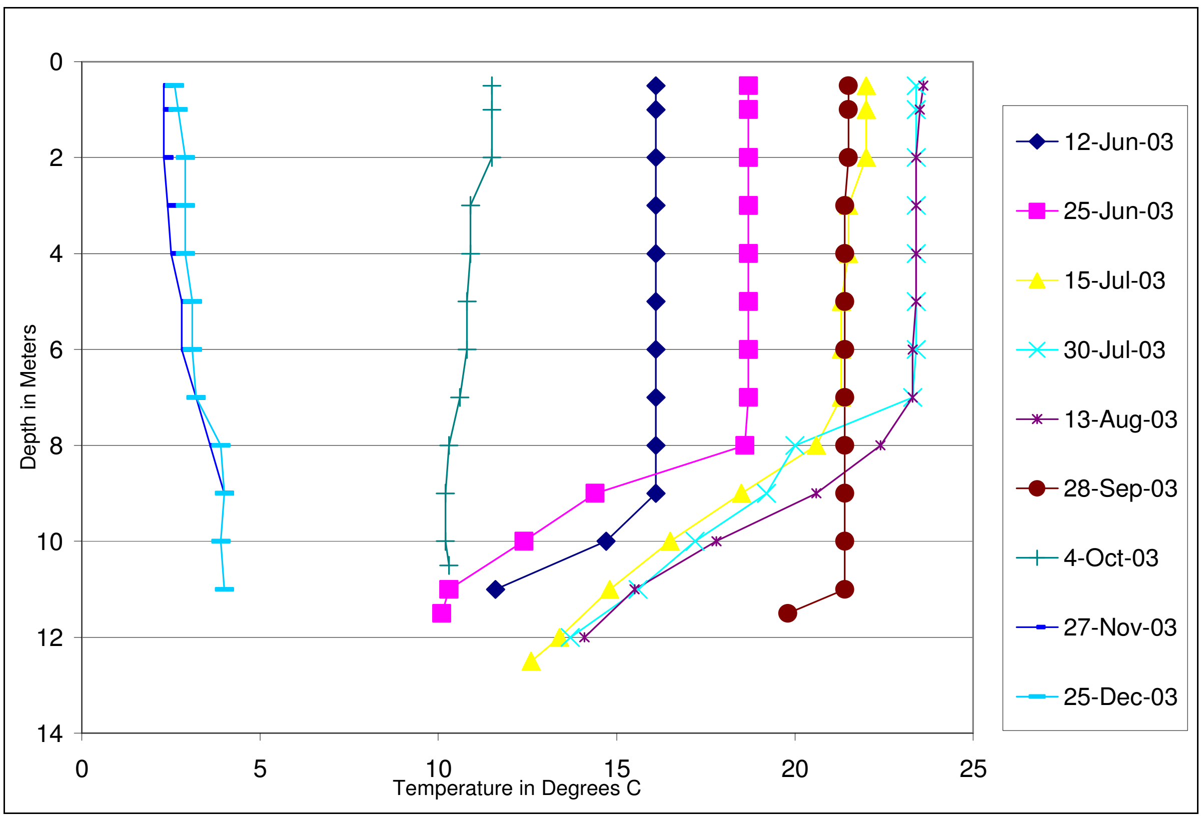


Figure 6. Summary of Temperature Data for the Blacktail Dam Deepest Area Site (380540) in 2003.

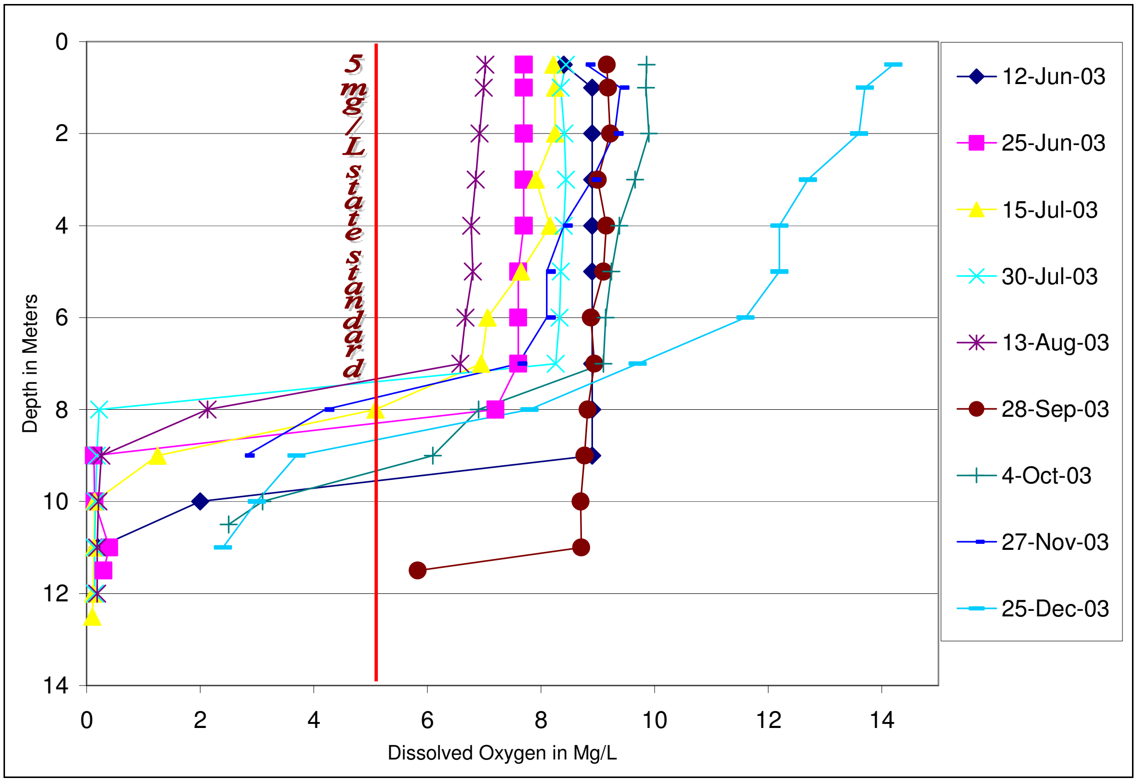


Figure 7. Summary of Dissolved Oxygen Concentrations for the Blacktail Dam Deepest Area Site (380540) in 2003.

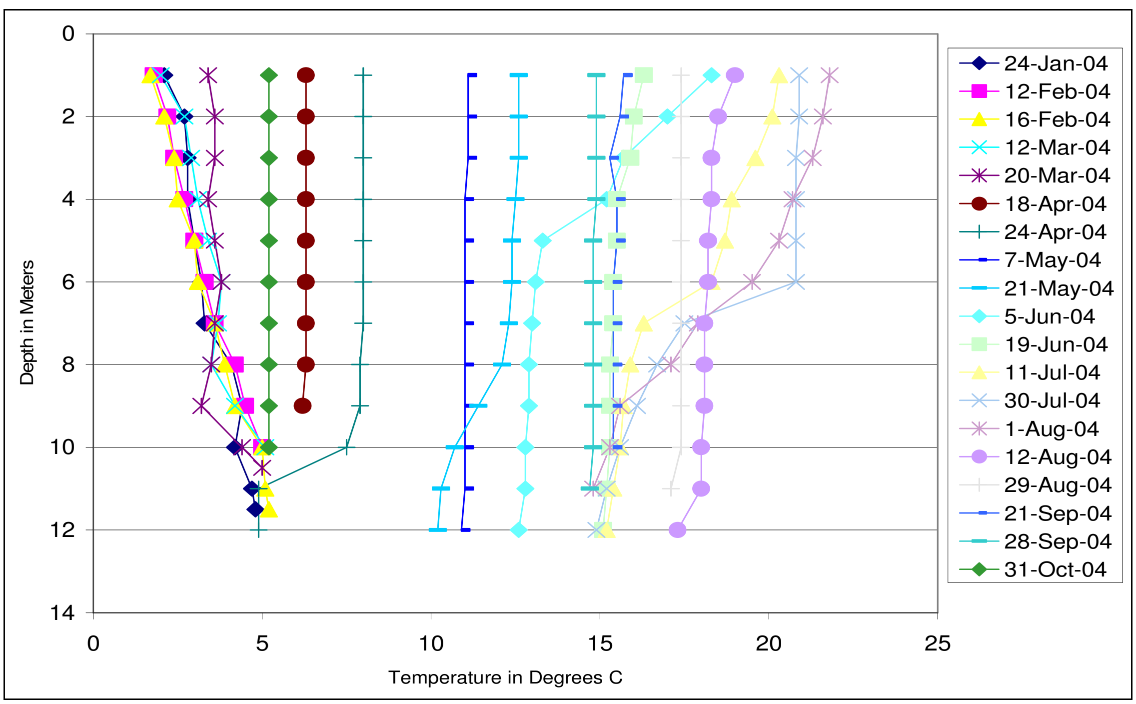


Figure 8. Summary of Temperature Data for the Blacktail Dam Deepest Area Site (380540) in 2004.

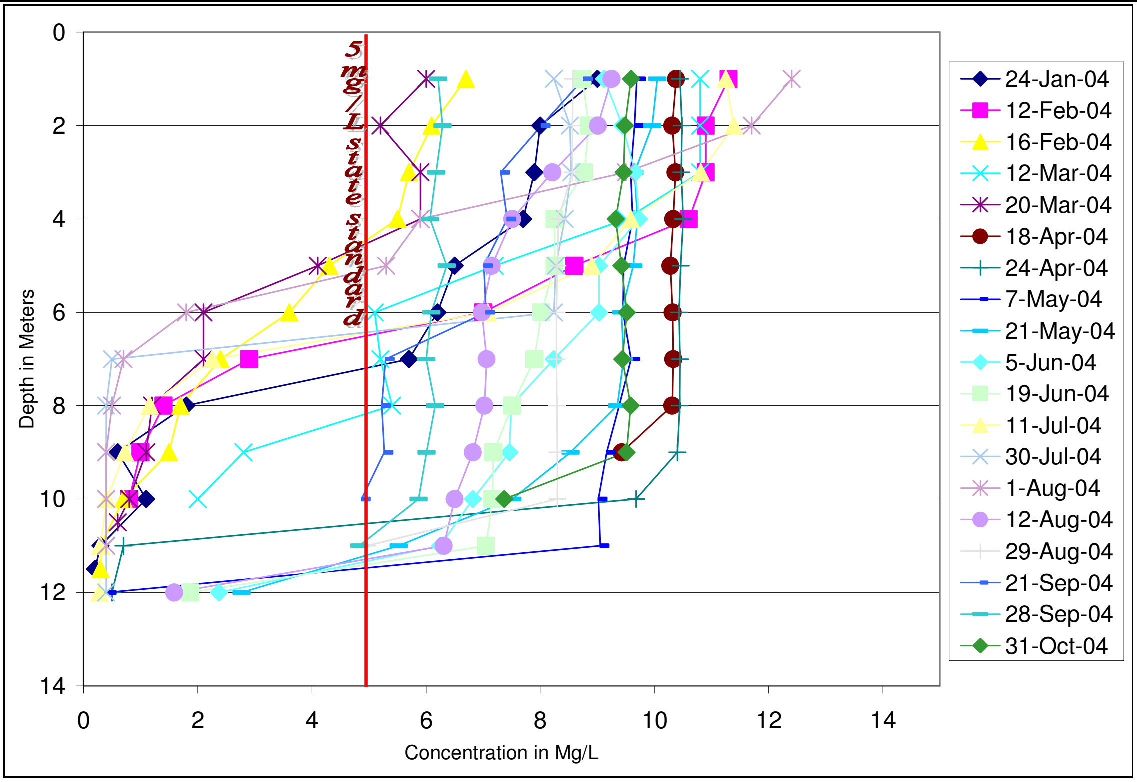


Figure 9. Summary of Dissolved Oxygen Concentrations for the Blacktail Dam Deepest Area Site (380540) in 2004.

<u>Secchi Disk Transparency and In-Lake Total Suspended Solids</u>

Throughout the course of the sampling effort, Blacktail Dam yielded an average Secchi disk transparency of 2.5 meters (8 feet, 2 inches). Of the 18 Secchi disk measurements, 6.3 meters (20 feet, 6 inches) was the maximum depth and 1.1 meters (3 feet, 6 inches) was the minimum depth recorded (Figure 10).

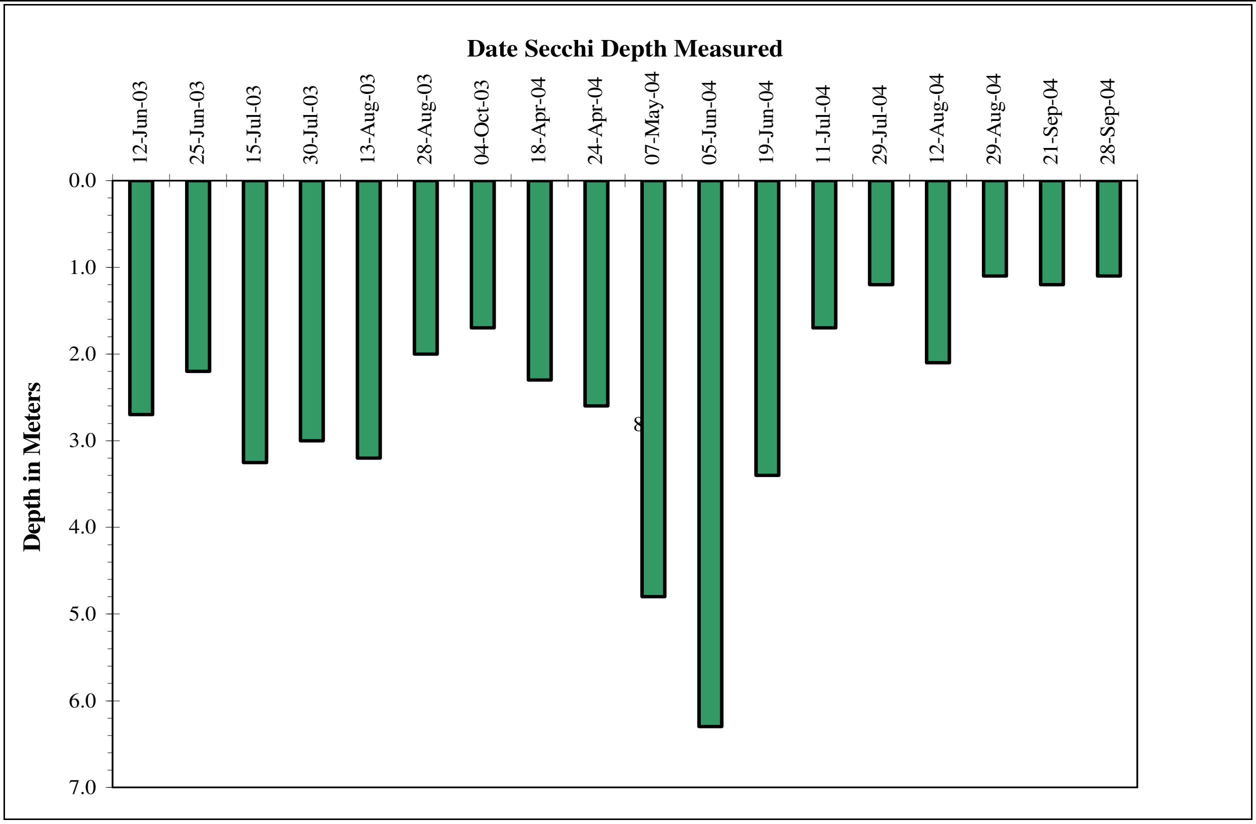


Figure 10. Blacktail Dam Secchi Disk Transparency Measurements.

Water clarity in a reservoir can be affected by many factors. Algal biomass, total suspended solids, and other debris can all affect Secchi disk transparency. Monthly total suspended solid (TSS) data indicate that algal biomass is the main factor limiting water clarity in Blacktail Dam. Table 7 shows that during the time of year when TSS loading is typically greatest (spring and early summer), Secchi disk transparency was the greatest and during mid to late summer, when algal biomass and plant matter are typically at a maximum, Secchi disk transparency was lowest. It can therefore be assumed that water clarity, as represented by Secchi Disk Tranparency, is due primarily to algal blooms. Due to this fact, a reduction in nutrient loading into the reservoir should decrease algal biomass and increase water clarity.

Table 7. Monthly Average Secchi Disk Transparency Depths for Blacktail Dam (2003-2004).

Month	Secchi Disk Depth (M)	Month	Secchi Disk Depth (M)
January	NA	July	2.3
February	NA	August	2.1
March	NA	September	1.2
April	2.5	October	1.7
May	4.8	November	NA
June	3.7	December	NA

Tributary Total Suspended Solids

Sixty-nine total suspended solid (TSS) samples were collected by the Williams County Soil Conservation District between June 2003 and October 2004. TSS samples were collected from two inlet sites (385239) and (385240) and one outlet site (385241) of Blacktail Dam. Average TSS concentrations at the north and south inlet sites were 8.2 and 12.1 mg/L, respectively. The average concentration at the outlet site was 8.9 mg/L (Table 8). These data indicate that suspended solids are being retained within the reservoir when comparing the mean concentration of the two inlet sites to the outlet site.

Table 8. Average Total Suspended Solid Concentrations for Blacktail Dam Inlet and Outlet Sites (2003-2004).

Site ID	Site Description	Average TSS (mg/L)
385240	North Inlet	8.2
385239	South Inlet	12.1
385241	Outlet	8.9

2.0 WATER QUALITY STANDARDS

The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be developed for waters on a state's Section 303(d) list. A TMDL is defined as “the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background” such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. The purpose of a TMDL is to identify the pollutant load reductions or other actions that should be taken so that impaired waters will be able to attain water quality standards. TMDLs are required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. Separate TMDLs are required to address each pollutant or cause of impairment (i.e., nutrients, dissolved oxygen).

2.1 Narrative Water Quality Standards

The North Dakota Department of Health has set narrative water quality standards that apply to all surface waters in the state. The narrative standards pertaining to nutrient and sediment impairments are listed below (NDDoH, 2006).

- All waters of the state shall be free from substances attributable to municipal, industrial, or other discharges or agricultural practices in concentrations or combinations that are toxic or harmful to humans, animals, plants, or resident aquatic biota.

- No discharge of pollutants, which alone or in combination with other substances, shall:
  - Cause a public health hazard or injury to environmental resources;
  - Impair existing or reasonable beneficial uses of the receiving water; or
  - Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters.

In addition to the narrative standards, the NDDoH has set a biological goal for all surface waters in the state. The goal states that “the biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites” (NDDoH, 2006).

2.2 Numeric Water Quality Standards

Blacktail Dam is classified as a Class 3 warm water fishery. Class 3 fisheries are "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota" (NDDoH, 2006). Some cool water species may also be present. All classified North Dakota lakes are assigned recreation, aquatic life, irrigation, livestock watering, and wildlife beneficial uses. Those beneficial uses threatened in Blacktail Dam include recreation and fish and other aquatic biota. Blacktail Dam's beneficial uses are fully supporting, but threatened as a result of nutrient enrichment, low dissolved oxygen, and sedimentation. The State Water Quality Standards state that lakes shall use the same numeric criteria as Class 1 streams. This includes the state standard for dissolved oxygen set at no less than 5 mg/L and nitrate as N as 1.0 mg/L. The State water quality standards also specify guidelines for lake or reservoir improvement programs as well (Table 9).

Table 9. Numeric Guidelines for Classified Lakes and Reservoirs (NDDoH, 2006).

Parameter	Guidelines	Limit
Guidelines or Standards for Classified Lakes:		
Nitrates (dissolved)	1.0 mg/L	Maximum allowed[1]
Dissolved Oxygen	5 mg/L	Not less than
Guidelines for goals in a lake improvement or maintenance program:		
NO_3 as N	0.25 mg/L	Goal
PO_4 as P	0.02 mg/L	Goal

[1] "The water quality standard for nitrates dissolved (N) is intended as an interim guideline limit. Since each stream or lake has unique characteristics which determine the levels of these constituents that will cause excessive plant growth (eutrophication), the department reserves the right to review this standard after additional study and to set specific limitations on any waters of the state. However, in no case shall the concentration for nitrate plus nitrite as N exceed 10 mg/l for any waters used as municipal or drinking water supply".

3.0 TMDL TARGETS

A TMDL target is the value that is measured to judge the success of the TMDL effort. TMDL targets must be based on state water quality standards, but can also include site specific values when no numeric criteria are specified in the standard. The following sections summarize water quality targets for Blacktail Dam based on its beneficial uses. If the specific target is met, it is assumed the reservoir will meet the applicable water quality standards, including its designated beneficial uses.

3.1 Nutrient Target

A Carlson's Trophic State Index (TSI) target of 60.07 based on total phosphorus was chosen for the Blacktail Dam endpoint. North Dakota's 2006 Integrated Section 305(b) and Section 303(d) Water Quality Assessment Report indicates that Carlson's Trophic State Index (TSI) is the primary indicator used to assess beneficial uses of the state's lakes and reservoirs (NDDoH, 2006). Trophic status is the measure of productivity of a lake or reservoir and is directly related to the level of nutrients (phosphorus and nitrogen) entering the lake or reservoir from its watershed. Lakes tend to become eutrophic (more productive) with higher nitrogen and phosphorus inputs. Eutrophic lakes often have nuisance algal blooms, limited water clarity, and low dissolved oxygen concentrations that can result in impaired aquatic life and recreational uses. Carlson's TSI attempts to assess the trophic state of a lake using nitrogen, phosphorus, chlorophyll-a, and Secchi disk transparency measurements (Carlson, 1977).

TSI values were calculated for total phosphorus, chlorophyll-*a*, and Secchi disk at Blacktail Dam. The highest TSI value was for total phosphorus at 67, while chlorophyll-*a* and Secchi disk values were 57 and 47, respectively (Table 10). Based on Carlson's TSI and water quality data collected between June 2003 and October 2004, Blacktail Dam was generally assessed as a eutrophic lake (Table 10). Eutrophic lakes are characterized by large growths of weeds, blue-green algal blooms, and low dissolved oxygen concentrations. These lakes may experience periodic fish kills and are generally characterized as having excessive rough fish populations (carp, bullhead, and sucker) that reflect negatively on the sport fishery. Due to frequent algal blooms and excessive weed growth, these lakes often become undesirable for recreational uses such as swimming and boating.

Table 10. Carlson's Trophic State Indices for Blacktail Dam.

TSI Parameter	Relationship	Units	TSI Value[1]
Secchi Disk (SD)	TSI (SD) = 60 – 14.41[ln(SD)]	meters	47
Chlorophyll-*a* (CHL)	TSI (CHL) = 30.6 + 9.81[ln(CHL)]	µg/L	57
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[ln(TP)]	µg/L	67

[1]TSI values were calculated using average surface TSI values from the Blacktail Dam in-lake monitoring station.
TSI < 38 = Oligotrophic (least productive)
TSI 38 – 52 = Mesotrophic
TSI 52 – 68 = Eutrophic
TSI > 68 = Hypereutrophic (most productive)

The reasons for the different TSI values estimated for Blacktail Dam are varied. According to the phosphorus TSI value, Blacktail Dam is an extremely productive lake (eutrophic to hypereutrophic) (Figure 11). Carlson and Simpson (1996) suggest that if the phosphorus and Secchi depth TSI values are relatively similar and higher than the chlorophyll-*a* TSI value, then dissolved color or nonalgal particulates dominate light attenuation. It follows that, if the Secchi depth and chlorophyll-*a* TSI values are similar, then chlorophyll-*a* is dominating light attenuation. Carlson and Simpson (1996) also state that a nitrogen index value might be more universally applicable than a phosphorus index, but it also means that a correspondence of the nitrogen index with the chlorophyll-*a* index cannot be used to indicate nitrogen limitation.

An analysis of temporal TSI trends indicate that total phosphorus may not be the only factor limiting algal biomass production. Phosphorus values from July through August 2003 and January through March of 2004 are significantly higher than chlorophyll-*a* values, suggesting that all available phosphorus is not being utilized (Figure 11).

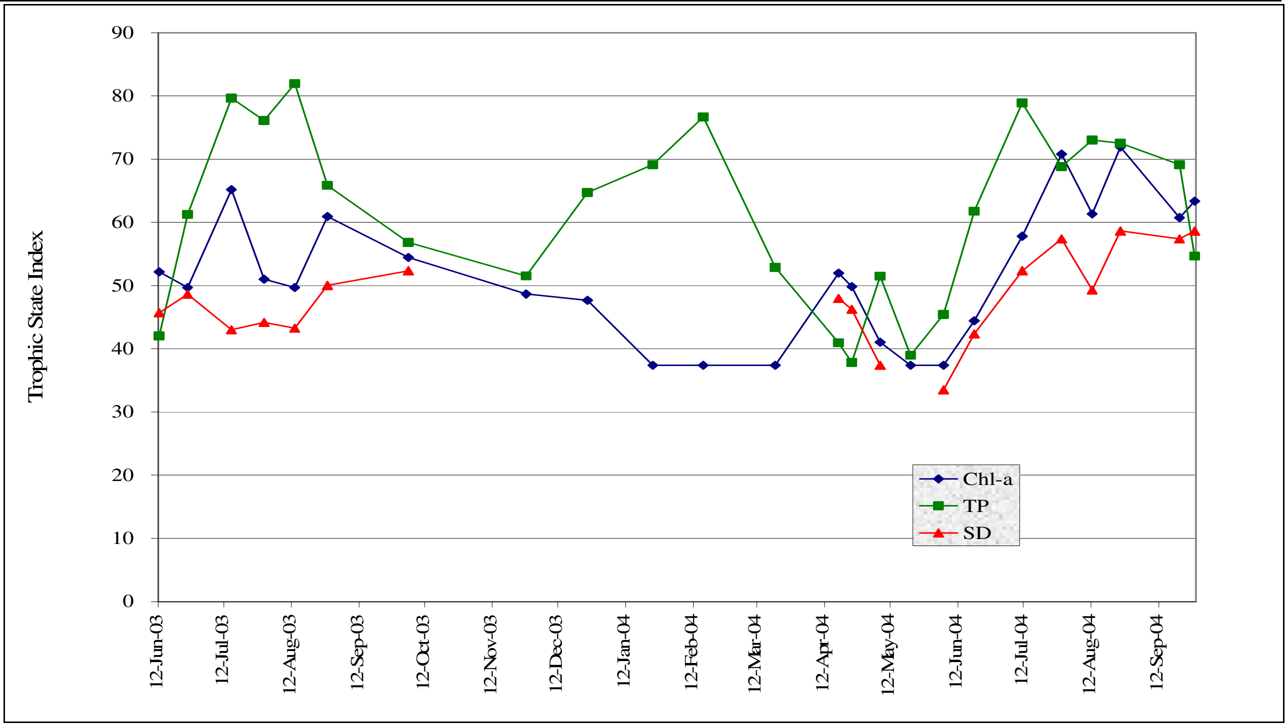


Figure 11. Seasonal Variation of Chlorophyll-*a*, Total Phosphorus and Secchi Disk TSI Values.

While the TSI target of 60.07 based on total phosphorus will not bring the concentration of total phosphorus to the State Water Quality Standard guideline goal for in-lake improvement (0.02 mg/L), it should result in a change of trophic status for the lake from borderline hypereutrophic to eutrophic during all times of the year. Given the size of the lake, the probable amount of phosphorus in bottom sediments, nearly constant wind in North Dakota causing a mixing effect, and few cost effective ways to reduce in-lake nutrient cycling, this was determined to be the best possible outcome for the reservoir. If the specified TMDL TSI target of 60.07 based on total P is met, the reservoir can be expected to meet the applicable water quality standards for aquatic life and recreational beneficial uses.

3.2 Dissolved Oxygen Target

The North Dakota State Water Quality Standard for dissolved oxygen is "5 mg/L as a daily minimum" and will be the dissolved oxygen target for Blacktail Dam.

4.0 SIGNIFICANT SOURCES

There are no known point sources in the Blacktail Dam watershed. Nutrients and sediment impairing the reservoir's beneficial uses are from non-point sources. According to the 2003 National Agricultural Statistics Service (NASS) land use/land cover data, the dominant land use/land cover within the watershed is crop land and range or pasture land. The remainder of the watershed is farmsteads, roads and water (Table 3). The United States Department of Agriculture's Stream Visual Assessment Protocol was used to assess the riparian area of tributaries to Blacktail Dam. The assessment indicated that of 21 sites evaluated, 13 were ranked as fair, one good and seven were poor. Priority resource issues listed as impacting the riparian area include: excessive grazing, nutrient management, excessive erosion and sedimentation.

In addition to nonpoint nutrient sources from the watershed, a significant portion of Blacktail Dam's shoreline is developed. Currently, approximately 119 seasonal cabins and permanent residences exist on the reservoir (Table 15). Based on estimates of phosphorus loading from these systems (see Section 5.4 Septic System Loading Analysis) contributions from septic systems along the developed shoreline may be a significant source of nutrients impacting the quality of water in Blacktail Dam.

5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-stream water quality targets and pollutant source loading is a critical component of TMDL development. Identifying the cause-and-effect relationship between pollutant loads and the water quality response is necessary to evaluate the loading capacity of the receiving waterbodies. The loading capacity is the amount of a pollutant that can be assimilated by the waterbody while still attaining and maintaining water quality standards. This section discusses the technical analysis used to estimate existing loads to Blacktail Dam and the predicted trophic response of the reservoir to reductions in loading capacity.

5.1 Tributary Load Analysis

To facilitate the analysis and reduction of tributary inflow and outflow water quality and flow data, the FLUX program was employed. The FLUX program, also developed by the US Corps of Engineers Waterways Experiment Station (Walker, 1996), uses six calculation techniques to estimate the average mass discharge or loading that passes a given river or stream site. FLUX estimates loadings based on grab sample chemical concentrations and the continuous daily flow record. Load is therefore defined as the mass of a pollutant during a given time period (e.g., hour, day, month, season, year). The FLUX program allows the user, through various iterations, to select the most appropriate load calculation technique and data stratification scheme, either by flow or date, which will give a load estimate with the smallest statistical error, as represented by the coefficient of variation. Output from the FLUX program (Appendix B) is then provided as an input file to calibrate the BATHTUB eutrophication response model. For a complete description of the FLUX program the reader is referred to Walker (1996).

5.2 BATHTUB Trophic Response Model

The BATHTUB model (Walker, 1996) was used to predict and evaluate the effects of various nutrient load reduction scenarios on Blacktail Dam. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network. The model accounts for advective and diffusive transport and nutrient sedimentation. Eutrophication related water quality conditions are predicted using empirical relationships previously developed and tested for reservoir applications.

The BATHTUB model is developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data. The third phase involves model calibration. In the data reduction phase, the in-lake and tributary monitoring data collected as part of the project were summarized in a format which can serve as inputs to the model.

The tributary data were analyzed and reduced by the FLUX program. FLUX uses tributary inflow and outflow water quality and flow data to estimate the average mass discharge or loading that passes a river or stream site using six calculation techniques. Load is therefore defined as the mass of pollutant during a given unit of time. The FLUX model then allows the user to pick the most appropriate load calculation technique with the smallest statistical error. Output from the FLUX program is then used to calibrate the BATHTUB model.

The reservoir data were reduced in Excel using three computational functions. These include: 1) the ability to display concentrations as a function of depth, location, or date; 2) summary statistics (mean, median, etc.); and 3) evaluation of trophic status. The output data from the Excel program were then used to calibrate the BATHTUB model.

When the input data from the FLUX and Excel programs are entered into the BATHTUB model the user has the ability to compare predicted conditions (model output) to actual conditions using general rates and factors. The BATHTUB model is then calibrated by combining tributary load estimates for the project period with in-lake water quality estimates. The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates from the project monitoring data. BATHTUB then has the ability to predict total phosphorus concentration, chlorophyll-a concentration, and Secchi disk transparency and the associated TSI scores as a means of expressing trophic response.

As stated above, BATHTUB can compare predicted vs. actual conditions. After calibration, the model was run based on observed concentrations of phosphorus and nitrogen to derive an estimated annual average total phosphorus load of 55.3 kg and an annual average total nitrogen load of 746.7 kg (Table 11, Appendix C). The model was then run to evaluate the effectiveness of a number of nutrient reduction alternatives including: 1) reducing externally derived nutrient loads; 2) reducing internally available nutrients; and 3) reducing both external and internal nutrient loads.

Table 11. Annual Loading (kg) of Total Phosphorus and Total Nitrogen for Blacktail Dam Based on the BATHTUB Model Analysis.

Contributing Area (Station)	Total Nitrogen	Total Phosphorus
North Tributary (385240)	413.8	22.0
South Tributary (385239)	272.9	27.3
Ungauged Inlet	60.0	6.0
Total Inlet	746.7	55.3
Outlet (385241)	1,408.5	157.0

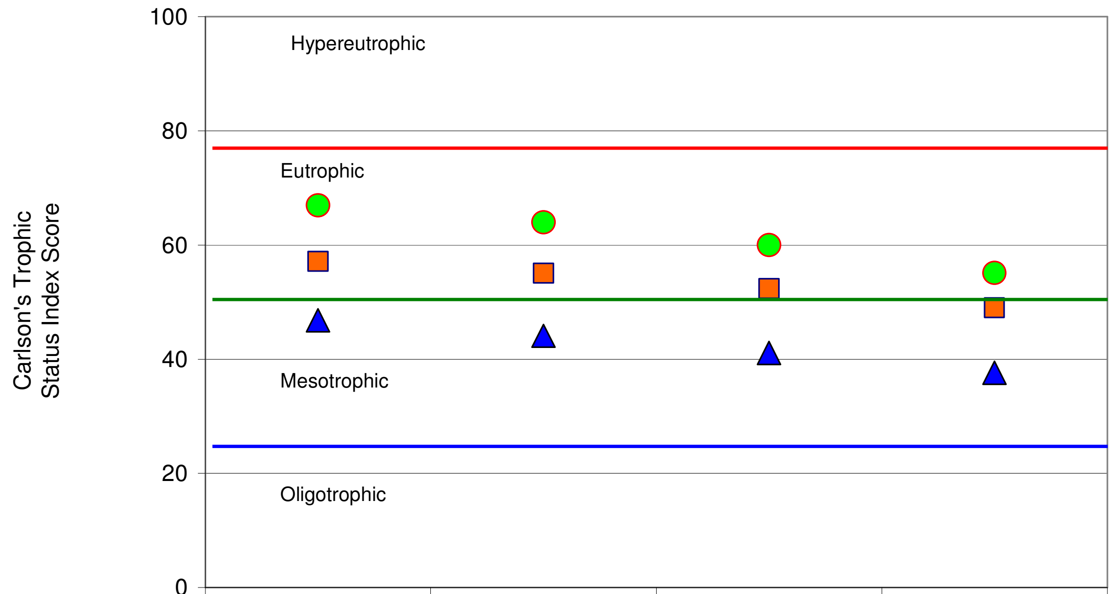
In the case of Blacktail Dam, BATHTUB modeled externally derived phosphorus. Phosphorus was used in the simulation model based on its known relationship to eutrophication and that it is controllable with the implementation of watershed Best Management Practices (BMPs). Changes in trophic response were evaluated by reducing externally derived phosphorus loading by 25, 50, and 75 percent. Simulated reductions were achieved by reducing phosphorus concentrations in contributing tributaries and other externally delivered sources. Flow was held constant due to uncertainty in estimating changes in hydraulic discharge with the implementation of BMPs.

With a 50 percent reduction in external phosphorus load, the model predicts a reduction in Carlson's TSI score from 57.17 to 52.37 for chlorophyll-a, and 46.80 to 41.11 for Secchi disk transparency, corresponding to a trophic state of nearly mesotrophic. More important for the long term health of the lake, is the predicted reduction in the total phosphorus TSI score of 66.97 to 60.07 which is a change from nearly hypertrophic to a low eutrophic TSI score (Table 12, Appendix D).

Table 12. Observed and Predicted Values for Selected Trophic Response Variables Assuming a 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading.

Variable	Observed Value	Predicted Value 25%	Predicted Value 50%	Predicted Value 75%
Total Phosphorus (mg/L)	0.077	0.063	0.048	0.034
Total Dissolved Phosphorus (mg/L)	0.027	0.042	0.036	0.024
Total Nitrogen (mg/L)	1.031	0.890	0.743	0.601
Organic Nitrogen (mg/L)	0.882	0.767	0.652	0.546
Chlorophyll-a (μg/L)	15.00	12.06	9.20	6.52
Secchi Disk Transparency (meters)	2.50	3.01	3.71	4.73
Carlson's TSI for Phosphorus	66.97	63.97	60.07	55.11
Carlson's TSI for Chlorophyll-a	57.17	55.03	52.37	49.00
Carlson's TSI for Secchi Disk	46.80	44.10	41.11	37.61

To acquire a noticeable change in the trophic status the BATHTUB model predicted that a 50 percent reduction in total phosphorus load would achieve the in-lake total phosphorus concentration target of 0.048 mg/L and an in-lake total nitrogen concentration of 0.743 mg/L. This reduction in phosphorus and nitrogen is predicted to result in a reservoir that is nearly mesotrophic at all times of the year (Table 12 and Figure 12).



	Observed	Less 25%	Less 50%	Less 75%
TSI-Phosphorus	66.97	63.97	60	55.11
TSI-Chlorophyll	57.17	55.03	52.37	49
TSI-Secchi Disk	46.8	44.1	41.11	37.61

Figure 12. Predicted Trophic Response in Blacktail Dam to a 25, 50, and 75 Percent Phosphorus Load Reduction.

5.3 AGNPS Watershed Model

In order to identify significant NPS pollutant sources in the Blacktail Dam watershed and to assess the relative reductions in nutrient (nitrogen and phosphorus) and sediment loading that can be expected from the implementation of BMPs in the watershed, an AGNPS 3.65 Model analysis was employed.

The primary objectives for using the AGNPS 3.65 model were to: 1) evaluate NPS contributions within the watershed; 2) identify critical pollutant source areas within the watershed; and 3) evaluate potential pollutant (nitrogen, phosphorus, and sediment) reduction estimates that can be achieved through various BMP implementation scenarios.

The AGNPS 3.65 model is a single event model that has twenty input parameters. Sixteen parameters were used to calculate nutrient/sediment output, surface runoff, and erosion. The parameters used where receiving cell, aspect, SCS curve, percent slope, slope shape, slope length, Manning's roughness coefficient, K-factor, C-factor, P-factor, surface conditions constant, soil texture, fertilizer inputs, point source indicators, COD factor and channel indicator.

The AGNPS 3.65 model was used in conjunction with an intensive land use survey to determine critical areas within the Blacktail Dam watershed. Criteria used during the land-use assessment include percent cover on cropland and pasture/range conditions. These criteria were used to determine the C factor for each cell. The model was run using current conditions determined during the land-use assessment. Other than the low density urban development around Blacktail Dam, the land use survey required for AGNPS data input files identified that 100 percent of the watershed is in agricultural production or in support of agricultural production such as farmsteads and farm-to-market roads.

Based on land use and watershed characteristics during the TMDL study, current annual runoff and annual nutrient yields were calculated for the watershed using the AGNPS model (Table 13).

Additional modeling comparisons were made by changing land-use practices on selected portions of the watershed. The watershed was divided into 437 40-acre cells for evaluation. Each cell was evaluated for soil characteristics, terrain, and land-use characteristics (Table 14).

The AGNPS model predicted that with the 2003-04 farming practices being utilized in the Blacktail Dam watershed, composed of a mixture of cropland, CRP and rangeland, the total nitrogen in sediment yield would be 0.58 pounds per acre and the total phosphorus in sediment yield would be 0.29 pounds per acre (Table 14). However, by altering some of the land management practices in the watershed, a sizeable reduction in total nitrogen (TN) and total phosphorus (TP) can be expected. The following changes were input into the AGNPS model. Land practices in cells with a land slope greater than 5% were converted to CRP, no or zero till cultivation was applied to all row crop or small grain crops, and total containment of waste from the two concentrated livestock feeding operations in the watershed was put into the model as well. All alfalfa and pasture land in the watershed was left unchanged. A reduction in runoff yield of 0.18 lbs/acre (TN) and 0.09 lbs/acre (TP) is estimated to result from these practices (Table 14), resulting in an overall reduction of 31% in both TP and TN in the watershed.

Table 13. Runoff and Annual Yield Summary for the Blacktail Dam Watershed.

Watershed studied is	Blacktail Dam
The Area of the Watershed is	17,482 acres
The Area of Each Cell is	40.00 acres
The Characteristic Storm Precipitation is	4.00 inches
The Storm Energy-intensity Value is	98.49
Values at the Watershed Outlet	
Outlet Cell	338
Runoff Volume	1.84 Inches
Peak Runoff Rate	3,961 cfs
Total Nitrogen in Sediment	0.58 lbs/acre
Total Soluble Nitrogen in Runoff	0.37 lbs/acre
Soluble Nitrogen Concentration in Runoff	0.88 ppm
Total Phosphorus in Sediment	0.29 lbs/acre
Soluble Phosphorus Concentration in Runoff	0.02 lbs/acre
Total Soluble Chemical Oxygen Demand in Runoff	35.75 lbs/acre
Soluble Chemical Oxygen Demand Concentration in Runoff	85.79 ppm
Total Sediment	1919.3 tons
Mean Concentration	478.72 ppm
Area Weighed Erosion (Upland)	2.77 +/acre

Table 14. Blacktail Dam Watershed AGNPS Summary.

Watershed Studied			
Area of Watershed	17,482 acres		
Area of Each Cell	40 acres		
Characteristic Storm Precipitation	4 inches		
Storm Energy-Intensity Value	98.49 inches		
Values at the Watershed Outlet			
Original	**2003-2004 Conditions**	**No till/ total containment**	**>5%slope to CRP**
Number of Cells	481		
Runoff Volume	1.84 inches		
Peak Run-off Rate	3,961 cfs		
Total Nitrogen in Sediment Yield	0.58 lbs/acre	0.48 lbs/acre	0.40 lbs/acre
Total Soluble Nitrogen in Runoff Yield	0.37 lbs/acre		
Soluble Nitrogen Concentration in Runoff	0.88 ppm		
Total Phosphorus in Sediment Yield	0.29 lbs/acre	0.24 lbs/acre	0.20 lbs/acre
Total Soluble Phosphorus in Runoff Yield	0.02 lbs/acre		
Soluble Phosphorus Concentration in Runoff	0.05 ppm		
Total Soluble Chemical Oxygen Demand in Runoff Yield	35.75 lbs/acre		
Soluble Chemical Oxygen Demand Concentration in Runoff	85.79 ppm		

5.4 Septic System Loading Analysis

Although not directly measured, phosphorus contributions from cabin septic systems surrounding Blacktail Dam are expected to have an influence on nutrient loading and water quality as well. Accurate estimates of phosphorus loading directly from septic systems surrounding Blacktail Dam can not be made from empirical data. However, the following equation was utilized to assess and illustrate the potential for phosphorus loading from septic systems (Reckhow and others, 1980):

$$M = E_S * (\text{number of capita years}) * (1 - S_R)$$

Where M = Annual phosphorus loading from septic systems;
E_S = an export coefficient; and
S_R = a soil retention coefficient.

The variable E_S represents a phosphorus export coefficient for septic systems. Typically, export coefficients (E_S) range from 1.1 lb per capita year (Reckhow and others, 1980; Panuska and Kreider, 2002) to 1.8 lb per capita year (Garn and others, 1996). It was assumed that the most likely E_S value for Blacktail Dam was 1.4 lb of phosphorus per capita year. The total number of capita years was estimated to be 123. This is based on the extrapolated number of full-time residents (11) times the average number of full-time residents per cabin (3.1) plus the extrapolated number of seasonal residents (108) times the average number of seasonal residents per cabin (2.9) times the fraction of time seasonal residents spend at their cabin each year (104 days/365 days) (Table 15). The variable S_R, a soil retention coefficient, represents an estimate of the system's ability to immobilize phosphorus based on the following four conditions: 1) phosphorus adsorption capacity of the soil; 2) natural drainage; 3) soil permeability; and 4) slope. A value of 0.75 (75 percent) was assumed for S_R.

Based on these assumptions the annual total phosphorus loading from septic systems is estimated to be 43 lb (20 kg) per year, or 36% of the existing load contributed from the watershed based on the BATHTUB model. Since the septic system loading was estimated and not directly measured, low and high estimates for the septic system value were also estimated by using low (0.5) and high (0.9) estimates of the S_R value. The possible low and high estimates of septic system loadings to Blacktail Dam were 17 lb (7.9 kg) and 86 lb (40 kg) per year of phosphorus, respectively.

Table 15. Survey Response Data from Cabin Owners at Blacktail Dam, 2004.

Surveys mailed	119
Surveys returned	95
Response rate	80%
Non-response surveys	16
Full-time resident responses	7
Seasonal resident responses	72
Extrapolated full-time residents	11
Extrapolated seasonal residents	108
Average number of full-time residents/cabin	3.1
Average number of seasonal residents/cabin	2.9
Average number of days/yr spent at seasonal cabin	104

Full-time resident extrapolation formula = (7/79) * 119
Seasonal resident extrapolation formula = (72/79) * 119

5.5 Dissolved Oxygen

Blacktail Dam is listed as fully supporting, but threatened for fish and aquatic biota uses due to dissolved oxygen levels observed below the North Dakota water quality standard. The North Dakota water quality standard for dissolved oxygen is "not less than 5.0 mg/L". For Blacktail Dam, low dissolved oxygen levels, primarily in hypolimnion during thermal stratification, appear to be related to excessive nutrient loading.

The cycling of nutrients in aquatic ecosystems is largely determined by oxidation-reduction (redox) potential and the distribution of dissolved oxygen and oxygen-demanding particles (Dodds, 2002). Dissolved oxygen gas has a strong affinity for electrons, and thus influences biogeochemical cycling and the biological availability of nutrients to primary producers such as algae. High levels of nutrients can lead to eutrophication, which is defined as the undesirable growth of algae and other aquatic plants. In turn, eutrophication can lead to increased biological oxygen demand and oxygen depletion due to the respiration of microbes that decompose the dead algae and other organic material.

AGNPS and BATHTUB models indicated that excessive nutrient loading is responsible for the low dissolved oxygen levels in Blacktail Dam. Wetzel (1983) summarized, "The loading of organic matter to the hypolimnion and sediments of productive eutrophic lakes increases the consumption of dissolved oxygen. As a result, the oxygen content of the hypolimnion is reduced progressively during the period of summer stratification."

Carpenter et al. (1998), has shown that nonpoint sources of phosphorous has lead to eutrophic conditions for many lakes/reservoirs across the U.S. One consequence of eutrophication is oxygen depletion caused by decomposition of algae and aquatic plants. They also document that a reduction in nutrients will eventually lead to the reversal of eutrophication and attainment of designated beneficial uses. However, the rates of recovery are variable among lakes/reservoirs. This supports the NDDoH's viewpoint that decreased nutrient loads at the watershed level will result in improved oxygen levels, the concern is that this process may take a significant amount of time (5-15 years).

In Lake Erie, heavy loadings of phosphorous have impacted the lake severely. Monitoring and research from the 1960's has shown that depressed hypolimnetic dissolved oxygen levels were responsible for large fish kills and large mats of decaying algae. Bi-national programs to reduce nutrients into the lake have resulted in a downward trend of the oxygen depletion rate since monitoring began in the 1970's. The trend of oxygen depletion has lagged behind that of phosphorous reduction, but this was expected (See: http://www.epa.gov/glnpo/lakeerie/dostory.html).

Nürnberg (1995, 1995a, 1996, 1997), developed a model that quantified duration (days) and extent of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that the AF is positively correlated with average annual total phosphorous (TP) concentrations. The AF may also be used to quantify response to watershed restoration measures which makes it very useful for TMDL development. Nürnberg (1996) developed several regression models that show nutrients control all trophic state indicators related to oxygen and phytoplankton in lakes and reservoirs. These models were developed from water quality characteristics using a suite of North American lakes. NDDoH has obtained from the North Dakota Game and Fish Department and/or calculated the morphometric parameters such as surface area (A_o = 147 acres; 0.59 km^2), mean depth (z = 16.0 feet; 4.88 meters), and the ratio of mean depth to the surface area ($z/A_o^{0.5}$ = 0.006) for Blacktail Dam which show that these parameters are within the range of lakes used by Nürnberg. Based on this information, the NDDoH is confident that Nürnberg's empirical nutrient-oxygen relationship holds true for North Dakota lakes and reservoirs. The NDDoH is also confident that prescribed BMPs will reduce external loading of nutrients to Blacktail Dam which will reduce algae blooms, thereby reducing hypolimnetic oxygen depletion rates resulting in increased oxygen levels over time.

Best professional judgment concludes that as levels of phosphorus are reduced by the implementation of best management practices, dissolved oxygen levels will improve. This is supported by the research of Thornton, et al (1990). They state that, "... as organic deposits were exhausted, oxygen conditions improved." To insure that the implementation of BMPs will reduce phosphorus levels and result in a corresponding increase in dissolved oxygen, water quality monitoring will be conducted as part of any watershed improvement project in accordance with an approved Quality Assurance Project Plan.

5.6 Sediment

A sediment balance was calculated for Blacktail Dam (Table 16). The time period over which this amount of sediment transport occurred was 1.005 years, therefore, sediment accumulated within the reservoir at a rate of 1,748.8 kg/yr.

Mulholland and Elwood (1982) state that the acceptable average accumulation rate of sediment within reservoirs is 2 cm/yr. Based on a conversion from mass of sediment storage to depth of sediment storage, it can be assumed that Blacktail Dam is accumulating sediment at a current rate that is considered acceptable for reservoirs.

Table 16. Sediment Balance for Blacktail Dam (2003-2004).

	Inflow	Outflow (kg)	Storage (kg)
Total Suspended Solids	10,586.7	8,829.1	1,757.6

In order to perform the conversion from mass to depth, the particle density of soil is needed. In most mineral soils the average density of particles is in the range of 2.6 to 2.7 g/cm^3. This narrow range reflects the predominance of quartz and clay minerals in the soil matrix. An average particle density of 2.65 g/cm^3 (the density of quartz), is often applied to soils comprised principally of silicate materials. Since soils in the Blacktail Dam watershed are mineral soils, the particle density of silicate minerals can be used to calculate a depth of sediment accumulation within the reservoir. However, for the sake of providing an implicit margin of safety, the low end of the range (2.6 g/cm^3) will be used to calculate the equivalent depth of 1,748.8 kg of sediment transported in one year into Blacktail Dam.

Based on a sediment loading rate of 1,748,800 g/yr times a sediment density of 2.60 g/cm, the sediment volume deposited in Blacktail Dam is 672,615 cm^3 each year.

$$(1{,}748{,}800 \text{ g/yr}) / (2.60 \text{ g/cm}^3) = 673{,}000 \text{ cm}^3\text{/yr}$$

Based on a surface area of 147-acres (5,948,878,940 cm^2), the annual sedimentation rate is 0.00011 cm/year.

$$(673{,}000\ cm^3/yr) / (5{,}948{,}878{,}940\ cm^2) = 0.00011\ cm/yr$$

This estimated annual sediment accumulation rate is well below the average sedimentation rate of typical reservoirs.

Further support for the removal of TSS as a pollutant of concern can also be found in literature. Waters (1995) states that suspended sediment concentrations less than 25 mg/L are not harmful to fisheries; between 25 and 80 mg/L reduces fish yield; between 80 and 400 mg/L is unlikely to display a good fishery; and suspended sediment concentration greater than 400 mg/L will exhibit a poor fishery. Therefore, research by Waters (1995) supports the view that mean TSS concentrations in Blacktail Dam of 10.2 mg/L is not considered harmful to fisheries. While four samples out of fifty-six exceeded the 25 mg/L concentration stated by Waters (1995) as capable of reducing fish yield, no samples exceeded the 80 mg/L deemed unlikely to display a good fishery. Therefore, it is the recommendation of this TMDL report, that in the next North Dakota Section 303(d) list cycle, Blacktail Dam should be de-listed for sediment impairments.

Justification for delisting is also based on the Natural Resource Conservation Service (NRCS) Sedimentation Rate Standard for reservoirs. This standard is set at 1/8 inch of sediment eroded from the watershed drainage area delivered and detained in the sediment pool over the 50-year expected life of the project. Therefore:

Assuming Watershed Area = 17,482 acres = 27.32 $mi.^2$ = $7.61515 \times 10^8\ ft^2$
and,
NRCS Sedimentation Rate Standard equals 1/8 inch = 0.125 inch = 0.01041667 ft over 50 years
then,
NRCS Sediment Standard Volume =

$$7.61515 \times 10^8\ ft^2 * 0.01041667\ ft = 7{,}932{,}460\ ft^3$$
$$\text{where: } 7{,}932{,}460\ ft^3 = 2.247156 \times 10^{11}\ cm^3$$

Compare this to the calculated annual sedimentation rate from observed data entering Blacktail Dam over 50 years:

Calculated sediment volume from data = 672,615 cm^3/yr * 50 years = $3.363 \times 10^7\ cm^3$.

Using the NRCS Sedimentation Rate Standard of 1/8 inch over 50 years, Blacktail Dam's predicted sedimentation accumulation rate would be $2.247156 \times 10^{11}\ cm^3$. When compared with the current sedimentation rate over 50 years entering the reservoir, $3.363 \times 10^7\ cm^3$ appears to be well under the predicted sedimentation rate standard.

6.0 MARGIN OF SAFETY AND SEASONALITY

6.1 Margin of Safety

Section 303(d) of the Clean Water Act and EPA's regulations require that "TMDLs should be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety (MOS) can either be incorporated into conservative assumptions used to develop the TMDL (implicit) or added as a separate component of the TMDL (explicit). For the purposes of this nutrient TMDL, a MOS of 10% of the loading capacity will be used as an explicit MOS.

Assuming the combined "normal" year tributary load, estimated septic system contribution, and loading from internal cycling to Blacktail Dam is 55.3 kg of total phosphorus and the TMDL reduction goal is a 50% reduction in total loading, then this would result in a TMDL target total phosphorus loading capacity of 27.65 kg of total phosphorus per year. Based on a 10 % explicit margin of safety, the MOS for the Blacktail Dam TMDL would be 2.76 kg of phosphorus per year.

Post-implementation monitoring related to the effectiveness of the TMDL controls can also be used to assure attainment of the targets, using adaptive management during the implementation phase.

6.2 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and the EPA's regulations require that a TMDL be established with seasonal variations. Blacktail Dam's TMDL addresses seasonality because the BATHTUB model incorporates seasonal differences in its prediction of annual total phosphorus and nitrogen loadings.

7.0 TMDL

Table 17 summarizes the nutrient TMDL for Blacktail Dam in terms of loading capacity (LC), wasteload allocations (WLA), load allocations (LA), and a margin of safety (MOS). The TMDL can be generically described by the following equation.

TMDL = LC = WLA + LA + MOS

where:

LC = loading capacity, or the greatest loading a waterbody can receive without violating water quality standards;

WLA = wasteload allocation, or the portion of the TMDL allocated to existing or future point sources;

LA = load allocation, or the portion of the TMDL allocated to existing or future non-point sources;

MOS = margin of safety, or an accounting of the uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of the loading capacity as a MOS.

7.1 Nutrient TMDL

Table 17. Summary of the Phosphorus TMDL for Blacktail Dam.

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	55.3	Determined through the BATHTUB model
Loading Capacity	27.65	50 percent total reduction based on BATHTUB modeling
Wasteload Allocation	0.0	No point sources
Load Allocation	24.89	Entire loading capacity minus MOS is allocated to non-point sources
MOS	2.76	10% of the loading capacity (27.65 kg/yr) is reserved as an explicit margin of safety

Based on data collected in 2003 and 2004, the existing load to Blacktail Dam is estimated at 55.3 kg/yr. Based on the BATHTUB and AGNPS modeling results, a 50% reduction in the existing total phosphorus loading to Blacktail Dam will result in a predicted TMDL target total phosphorus concentration of 0.048 mg/L, therefore the TMDL or Loading Capacity is 27.65 kg/yr. Assuming that 10% of the loading capacity is explicitly assigned to the MOS (2.76 kg) and there are no point sources in the watershed, then all of the remaining loading capacity is then assigned to the load allocation (24.89 kg/yr).

In order to express this phosphorus TMDL as a daily load the annual loading capacity of 27.65 kg/yr was divided by 365 days. Based on this analysis, the phosphorus TMDL, expressed as an average daily load, is 0.0758 kg/day with the load allocation equal to 0.0682 kg/day and the MOS equal to 0.0076 kg/day.

7.2 Sediment TMDL

No reduction necessary, de-list for sediment.

7.3 Dissolved Oxygen TMDL

As a result of the direct influence of eutrophication on increased biological oxygen demand and microbial respiration, it is anticipated that meeting the phosphorus load reduction target in Blacktail Dam will address the dissolved oxygen impairment. A reduction in total phosphorus load to Blacktail Dam would be expected to lower algal biomass levels in the water column, thereby reducing the biological oxygen demand exerted by the decomposition of these primary producers. The reduction in biological oxygen demand is therefore assumed to result in attainment of the dissolved oxygen standard.

8.0 ALLOCATION

Blacktail Dam's watershed is small and supports extensive agriculture where cropland constitutes a majority of the land use. Sub-dividing it into smaller units, based on hydrology or type of conservation practice implemented, would not be practical. This TMDL will be implemented by several parties on a volunteer basis. Phosphorus loads into the reservoir will be reduced by treating the AGNPS identified critical cells (Figure 13). There are 220- 40 acre cells within the Blacktail Dam watershed identified as "critical" by the AGNPS model. Critical cells are those with fallow, small grains, or land chiseled multiple times; as well as feedlots (2), and all land with a slope greater than five percent. These cells represent a total area of 8,800 acres or 50 percent of the watershed. If these critical areas in the watershed are targeted for treatment with BMPs (e.g., no till, nutrient management, grazing systems, native/tame grass seeding on steep slopes, etc.), then the specified phosphorus load reduction of 27.65 kg is possible.

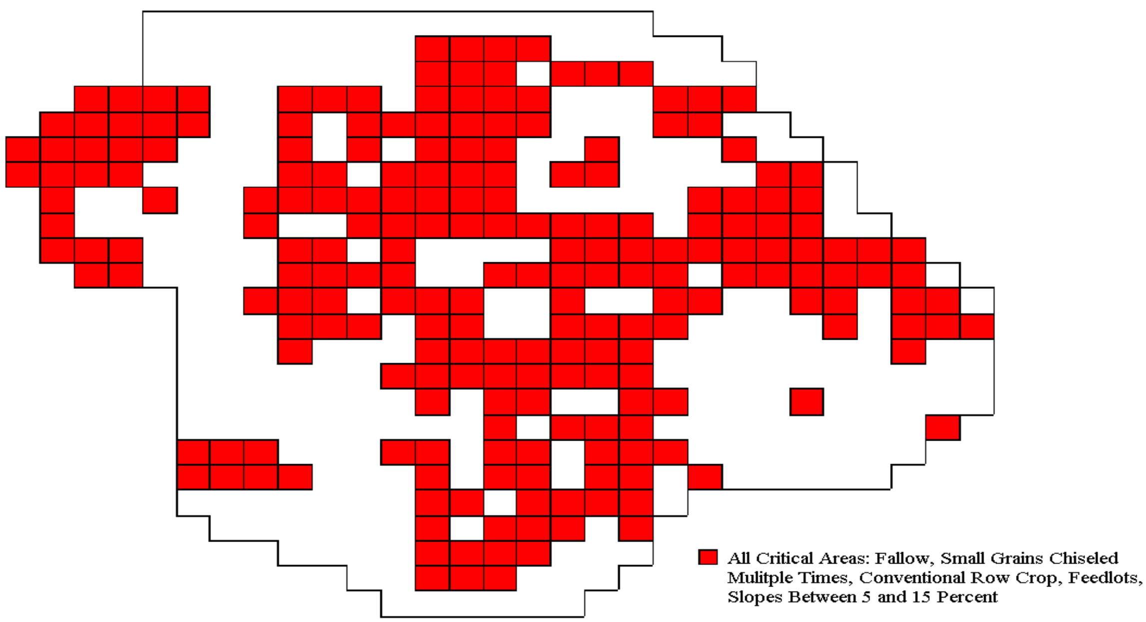


Figure 13. AGNPS Identification of Critical Areas for BMP Implementation.

Based on the septic system survey results and load analysis (see section 5.4), failing and/or poorly designed septic systems surrounding Blacktail Dam may be a significant source of nutrient loading to the reservoir. While the specific percent contribution is unknown, a 50% reduction in the estimated septic system phosphorus load could be reasonably expected through updates in current septic systems to total containment. As part of any watershed implementation plan, further study and analysis should be conducted on the extent and condition of failing septic systems surrounding the lake. This is necessary further quantify the contribution of septic systems to the lake's nutrient load.

Reductions in net nutrient loading will continue to be achieved through the operation of the existing hypolimnetic discharge system. Continued operations of this system will result in a decrease in net phosphorus loading and possibly lead to improved winter dissolved oxygen levels.

While it is believed that instituting BMPs will result in the needed water quality improvements, the history of sediment and nutrient deposition may strongly effect internal nutrient cycling. The correct use of the hypolimnetic draw down may aid in improving water quality, as well as provide an additional margin of safety for the phosphorus TMDL. Additionally, public willingness towards conservation practices will facilitate the implementation of the additional BMPs that are needed.

TMDLs in this report are a plan to improve water quality by implementing BMPs through a volunteer, incentive-based approach. This TMDL plan is put forth as a recommendation to what must be accomplished for Blacktail Dam and its watershed to meet and protect its beneficial uses. Water quality monitoring should continue to assess the effects of the recommendations made in this TMDL. Monitoring may indicate that the loading capacity recommendations should be adjusted.

9.0 PUBLIC PARTICIPATION

To satisfy the public participation requirement of this TMDL, a hard copy of the TMDL for Blacktail Dam and request for comment was mailed to participating agencies, partners, and to those requesting a copy. Those included in the hard copy mailing were:

- Williams County Soil Conservation District;
- Williams County Water Resource Board;
- Williams County Park Board;
- Blacktail Dam Association;
- Natural Resources Conservation Service (State and Williams County Field Offices);
- North Dakota Game and Fish Department – Williston District and Save Our Lakes Program;
- U.S. Fish and Wildlife Service; and
- U.S. Environmental Protection Agency, Region VIII.

In addition to the mailed copies, the TMDL for Blacktail Dam was posted on the North Dakota Department of Health, Division of Water Quality web site at http://www.health.state.nd.us/WQ/sw/Z2_TMDL/TMDLs_Under_PublicComment/B_Under_Public_Comment.htm . A 30 day public notice soliciting comment and participation was also published in the following newspapers:

- Williston Herald; and
- The Bismarck Tribune.

Comments were received from Scott Elstad and Fred Ryckman with the North Dakota Game and Fish Department. Editorial comments were incorporated where appropriate. In addition, the North Dakota Game and Fish Department also provided more specific formal comments. These comments and the Department's response to these comments are provided in Appendix F.

10.0 MONITORING

To insure that BMPs implemented as part of any watershed restoration plan will reduce phosphorus levels and result in a corresponding increase in dissolved oxygen, water quality monitoring will be conducted in accordance with an approved Quality Assurance Project Plan (QAPP).

Specifically, monitoring will be conducted for all variables that are currently causing impairments to the beneficial uses of the waterbody. These include, but are not limited to, nutrients (i.e., nitrogen and phosphorus) and dissolved oxygen. Once a watershed restoration plan (e.g. Section 319 Project Implemenation Plan) is implemented, monitoring will be conducted in the reservoir beginning two years after implementation and extending 5 years after the implementation project is complete.

11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 NPS funds or other watershed restoration programs (e.g. USDA EQIP), as well as securing a local project sponsor and the required matching funds. Provided these three requirements are in place, a project implementation plan (PIP) is developed in accordance with the TMDL and submitted to the ND Nonpoint Source Pollution Task Force and US EPA for approval. The implementation of the best management practices contained in the NPS pollution management project implementation plan (PIP) is voluntary. Therefore, success of any TMDL implementation project is ultimately dependent on the ability of the local project sponsor to find cooperating producers.

Monitoring is an important and required component of any PIP. As a part of the PIP, data are collected to monitor and track the effects of BMP implementation as well as to judge overall project success. Quality Assurance Project Plans (QAPPs) detail the strategy of how, when, and where monitoring will be conducted to gather the data needed to document the TMDL implementation goal(s). As data are gathered and analyzed, watershed restoration tasks are adapted to place BMPs where they will have the greatest benefit to water quality.

12.0 ENDANGERED SPECIES ACT COMPLIANCE

The North Dakota Department of Health has reviewed the list of Threatened and Endangered Species in Williams County as provided by the US Fish and Wildlife Service (Appendix E). Although there are listed species present in the county they do not utilize the waterbody that is targeted by this TMDL. It is, therefore, the Department's best professional judgment that the Blacktail Dam TMDL poses "No Adverse Effect" to those Threatened and Endangered species listed for Williams County.

As mentioned in Section 9.0, the US Fish and Wildlife Service was sent a copy of this document for their review during the public comment period. No comments were received from the US Fish and Wildlife Service, therefore we assume they concur with our assessment of "No Adverse Effect" to those Threatened and Endangered species listed for Williams County.

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Appendix A
Dissolved Oxygen and Temperature Data

Site #	Date	Depth	Temp	DO
380540	6/12/2003	0.5	16.1	8.4
380540	6/12/2003	1	16.1	8.9
380540	6/12/2003	2	16.1	8.9
380540	6/12/2003	3	16.1	8.9
380540	6/12/2003	4	16.1	8.9
380540	6/12/2003	5	16.1	8.9
380540	6/12/2003	6	16.1	8.9
380540	6/12/2003	7	16.1	8.9
380540	6/12/2003	8	16.1	8.9
380540	6/12/2003	9	16.1	8.9
380540	6/12/2003	10	14.7	2
380540	6/12/2003	11	11.6	0.2
380540	6/25/2003	0.5	18.7	7.7
380540	6/25/2003	1	18.7	7.7
380540	6/25/2003	2	18.7	7.7
380540	6/25/2003	3	18.7	7.7
380540	6/25/2003	4	18.7	7.7
380540	6/25/2003	5	18.7	7.6
380540	6/25/2003	6	18.7	7.6
380540	6/25/2003	7	18.7	7.6
380540	6/25/2003	8	18.6	7.2
380540	6/25/2003	9	14.4	0.13
380540	6/25/2003	10	12.4	0.14
380540	6/25/2003	11	10.3	0.4
380540	6/25/2003	11.5	10.1	0.3
380540	7/15/2003	0.5	22	8.22
380540	7/15/2003	1	22	8.25
380540	7/15/2003	2	22	8.25
380540	7/15/2003	3	21.5	7.91
380540	7/15/2003	4	21.5	8.16
380540	7/15/2003	5	21.3	7.65
380540	7/15/2003	6	21.3	7.06
380540	7/15/2003	7	21.3	6.95
380540	7/15/2003	8	20.6	5.09
380540	7/15/2003	9	18.5	1.25
380540	7/15/2003	10	16.5	0.14
380540	7/15/2003	11	14.8	0.13
380540	7/15/2003	12	13.4	0.12
380540	7/15/2003	12.5	12.6	0.1

Site #	Date	Depth	Temp	DO
380540	7/30/2003	0.5	23.4	8.44
380540	7/30/2003	1	23.4	8.35
380540	7/30/2003	2	23.4	8.41
380540	7/30/2003	3	23.4	8.44
380540	7/30/2003	4	23.4	8.4
380540	7/30/2003	5	23.4	8.35
380540	7/30/2003	6	23.4	8.33
380540	7/30/2003	7	23.3	8.26
380540	7/30/2003	8	20	0.22
380540	7/30/2003	9	19.2	0.18
380540	7/30/2003	10	17.2	0.16
380540	7/30/2003	11	15.6	0.14
380540	7/30/2003	12	13.7	0.15
380540	8/13/2003	0.5	23.6	7.02
380540	8/13/2003	1	23.5	6.99
380540	8/13/2003	2	23.4	6.92
380540	8/13/2003	3	23.4	6.85
380540	8/13/2003	4	23.4	6.77
380540	8/13/2003	5	23.4	6.8
380540	8/13/2003	6	23.3	6.67
380540	8/13/2003	7	23.3	6.58
380540	8/13/2003	8	22.4	2.13
380540	8/13/2003	9	20.6	0.26
380540	8/13/2003	10	17.8	0.21
380540	8/13/2003	11	15.5	0.19
380540	8/13/2003	12	14.1	0.19
380540	9/28/2003	0.5	21.5	9.16
380540	9/28/2003	1	21.5	9.18
380540	9/28/2003	2	21.5	9.22
380540	9/28/2003	3	21.4	9
380540	9/28/2003	4	21.4	9.15
380540	9/28/2003	5	21.4	9.1
380540	9/28/2003	6	21.4	8.88
380540	9/28/2003	7	21.4	8.94
380540	9/28/2003	8	21.4	8.82
380540	9/28/2003	9	21.4	8.77
380540	9/28/2003	10	21.4	8.7
380540	9/28/2003	11	21.4	8.71
380540	9/28/2003	11.5	19.8	5.83

Site #	Date	Depth	Temp	DO
380540	10/04/2003	0.5	11.5	9.86
380540	10/04/2003	1	11.5	9.85
380540	10/04/2003	2	11.5	9.9
380540	10/04/2003	3	10.9	9.66
380540	10/04/2003	4	10.9	9.38
380540	10/04/2003	5	10.8	9.24
380540	10/04/2003	6	10.8	9.14
380540	10/04/2003	7	10.6	9.1
380540	10/04/2003	8	10.3	6.9
380540	10/04/2003	9	10.2	6.1
380540	10/04/2003	10	10.2	3.1
380540	10/04/2003	10.5	10.3	2.5
380540	11/27/2003	0.5	2.3	8.8
380540	11/27/2003	1	2.3	9.4
380540	11/27/2003	2	2.3	9.3
380540	11/27/2003	3	2.4	8.9
380540	11/27/2003	4	2.5	8.4
380540	11/27/2003	5	2.8	8.1
380540	11/27/2003	6	2.8	8.1
380540	11/27/2003	7	3.2	7.6
380540	11/27/2003	8	3.6	4.2
380540	11/27/2003	9	4	2.8
380540	12/25/2003	0.5	2.6	14.2
380540	12/25/2003	1	2.7	13.7
380540	12/25/2003	2	2.9	13.6
380540	12/25/2003	3	2.9	12.7
380540	12/25/2003	4	2.9	12.2
380540	12/25/2003	5	3.1	12.2
380540	12/25/2003	6	3.1	11.6
380540	12/25/2003	7	3.2	9.7
380540	12/25/2003	8	3.9	7.8
380540	12/25/2003	9	4	3.7
380540	12/25/2003	10	3.9	3
380540	12/25/2003	11	4	2.4
380540	01/24/2004	1	2.1	9
380540	01/24/2004	2	2.7	8
380540	01/24/2004	3	2.8	7.9
380540	01/24/2004	4	2.8	7.7
380540	01/24/2004	5	3	6.5
380540	01/24/2004	6	3.2	6.2
380540	01/24/2004	7	3.3	5.7
380540	01/24/2004	8	4.1	1.8
380540	01/24/2004	9	4.4	0.6
380540	01/24/2004	10	4.2	1.1
380540	01/24/2004	11	4.7	0.3
380540	01/24/2004	11.5	4.8	0.2

Site #	Date	Depth	Temp	DO
380540	02/12/2004	1	1.8	11.3
380540	02/12/2004	2	2.2	10.9
380540	02/12/2004	3	2.4	10.9
380540	02/12/2004	4	2.7	10.6
380540	02/12/2004	5	3	8.6
380540	02/12/2004	6	3.3	7
380540	02/12/2004	7	3.6	2.9
380540	02/12/2004	8	4.2	1.4
380540	02/12/2004	9	4.5	1
380540	02/12/2004	10	5	0.8
380540	02/16/2004	1	1.7	6.7
380540	02/16/2004	2	2.1	6.1
380540	02/16/2004	3	2.4	5.7
380540	02/16/2004	4	2.5	5.5
380540	02/16/2004	5	3	4.3
380540	02/16/2004	6	3.1	3.6
380540	02/16/2004	7	3.6	2.4
380540	02/16/2004	8	3.9	1.7
380540	02/16/2004	9	4.2	1.5
380540	02/16/2004	10	5	0.7
380540	02/16/2004	11	5.1	0.3
380540	02/16/2004	11.5	5.2	0.3

Appendix B
Flux Data and Analysis

Blacktail Dam North Inlet 385240 Flux Load Analysis

```
            VAR=NH3-4     METHOD= 2 Q WTD C       VAR=NH3-4     METHOD= 4 REG-1
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .490         .350       -.345   .049
***       367  24  24 100.0         .490         .350

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .490 HM3/YR
 TOTAL FLOW VOLUME =        .49 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD            5.4            5.3      .1331E+01      10.89    .216
 2 Q WTD C            7.5            7.5      .2451E+01      15.24    .210
 3 IJC                7.3            7.3      .2166E+01      14.89    .202
 4 REG-1              6.7            6.6      .1138E+01      13.57    .160
 6 REG-3              7.1            7.0      .1957E+01      14.38    .199


            VAR=NO2+NO3   METHOD= 4 REG-1
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .490         .350       -.827   .004
***       367  24  24 100.0         .490         .350

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .490 HM3/YR
 TOTAL FLOW VOLUME =        .49 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD           19.3           19.2      .2171E+02      39.19    .243
 2 Q WTD C           27.0           26.9      .8353E+02      54.82    .340
 3 IJC               25.6           25.5      .7029E+02      52.08    .329
 4 REG-1             20.4           20.3      .1626E+02      41.53    .198
 6 REG-3             25.0           24.8      .5497E+02      50.71    .298
```

Blacktail Dam North Inlet 385240 Flux Load Analysis (con't)

```
            VAR=T-N       METHOD= 2 Q WTD C
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .490         .350       -.407   .028
***       367  24  24 100.0         .490         .350

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .490 HM3/YR
 TOTAL FLOW VOLUME =        .49 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD          297.2          295.8      .4966E+04     603.70    .238
 2 Q WTD C          415.7          413.7      .5563E+04     844.44    .180
 3 IJC              411.5          409.5      .6320E+04     835.97    .194
 4 REG-1            362.6          360.9      .1414E+05     736.60    .330
 6 REG-3            382.7          380.9      .1036E+05     777.53    .267


            VAR=TD-P      METHOD= 4 REG-1
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .490         .350       -.707   .002
***       367  24  24 100.0         .490         .350

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .490 HM3/YR
 TOTAL FLOW VOLUME =        .49 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD            6.2            6.2      .1971E+01      12.66    .226
 2 Q WTD C            8.7            8.7      .5752E+01      17.71    .276
 3 IJC                8.4            8.4      .5145E+01      17.10    .271
 4 REG-1              6.9            6.8      .2794E+01      13.97    .244
 6 REG-3              7.3            7.3      .3627E+01      14.91    .261
```

Blacktail Dam North Inlet 385240 Flux Load Analysis (con't)

```
            VAR=T-P       METHOD= 2 Q WTD C
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .490         .350       -.532   .007
***       367  24  24 100.0         .490         .350

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .490 HM3/YR
 TOTAL FLOW VOLUME =        .49 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD           15.8           15.8      .1496E+02      32.16    .246
 2 Q WTD C           22.1           22.0      .1828E+02      44.98    .194
 3 IJC               21.9           21.8      .1946E+02      44.47    .202
 4 REG-1             18.5           18.4      .2556E+02      37.62    .274
 6 REG-3             19.0           18.9      .2612E+02      38.51    .271

            VAR=TSS       METHOD= 2 Q WTD C
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  23  23 100.0         .490         .349        .319   .010
***       367  23  23 100.0         .490         .349

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .490 HM3/YR
 TOTAL FLOW VOLUME =        .49 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD         4439.4         4418.2      .3187E+07    9018.69    .404
 2 Q WTD C         6226.3         6196.6      .4798E+07   12648.81    .353
 3 IJC             6221.7         6192.0      .5003E+07   12639.42    .361
 4 REG-1           6936.2         6903.2      .9184E+07   14091.05    .439
 5 REG-2          69643.4        69311.3      .3691E+10  141481.10    .877
 6 REG-3           6159.3         6129.9      .5171E+07   12512.65    .371
```

Blacktail Dam South Inlet 385239 Flux Load Analysis

```
           VAR=NH3-4     METHOD= 2 Q WTD C
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .271        1.843       -.055   .256
***       367  24  24 100.0         .271        1.843

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .271 HM3/YR
 TOTAL FLOW VOLUME =        .27 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD           18.6           18.5      .1686E+03      68.47    .701
 2 Q WTD C            2.7            2.7      .1331E-02      10.05    .013
 3 IJC                2.7            2.7      .1164E-02      10.03    .013
 4 REG-1              3.0            3.0      .1191E+00      11.17    .114
 6 REG-3              2.8            2.8      .3282E-01      10.43    .064


           VAR=NO2+NO3   METHOD= 2 Q WTD C
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .271        1.843       -.398   .002
***       367  24  24 100.0         .271        1.843

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .271 HM3/YR
 TOTAL FLOW VOLUME =        .27 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD          149.0          148.3      .1374E+05     548.05    .791
 2 Q WTD C           21.9           21.8      .3930E+02      80.46    .288
 3 IJC               22.7           22.6      .5034E+02      83.65    .314
 4 REG-1             46.9           46.7      .5148E+03     172.67    .486
 5 REG-2            413.3          411.3      .3439E+06    1520.30   1.426
 6 REG-3             19.1           19.0      .3240E+02      70.25    .300
```

Blacktail Dam South Inlet 385239 Flux Load Analysis (con't)

```
            VAR=T-N       METHOD= 3 IJC
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .271        1.843        .090   .010
***       367  24  24 100.0         .271        1.843

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .271 HM3/YR
 TOTAL FLOW VOLUME =        .27 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD         1871.4         1862.5      .1725E+07    6884.72    .705
 2 Q WTD C          274.7          273.4      .2978E+02    1010.73    .020
 3 IJC              274.7          273.4      .1440E+02    1010.71    .014
 4 REG-1            231.0          229.9      .5930E+03     849.82    .106
 5 REG-2            431.2          429.1      .1247E+06    1586.26    .823
 6 REG-3            291.0          289.6      .1018E+04    1070.66    .110


            VAR=TD-P      METHOD= 6 REG-3
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .271        1.843        .031   .716
***       367  24  24 100.0         .271        1.843

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .271 HM3/YR
 TOTAL FLOW VOLUME =        .27 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD           89.8           89.4      .2821E+04     330.46    .594
 2 Q WTD C           13.2           13.1      .3215E+02      48.51    .432
 3 IJC               12.4           12.4      .4591E+02      45.77    .547
 4 REG-1             12.4           12.4      .3288E+02      45.70    .464
 5 REG-2             17.1           17.0      .4323E+03      62.88   1.222
 6 REG-3             15.9           15.8      .1259E+02      58.48    .224
```

Blacktail Dam South Inlet 385239 Flux Load Analysis (con't)

```
            VAR=T-P       METHOD= 3 IJC
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  24  24 100.0         .271        1.843       -.030   .561
***       367  24  24 100.0         .271        1.843

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .271 HM3/YR
 TOTAL FLOW VOLUME =        .27 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD          187.2          186.3      .1731E+05     688.51    .706
 2 Q WTD C           27.5           27.3      .1030E+01     101.08    .037
 3 IJC               27.5           27.4      .5039E+00     101.11    .026
 4 REG-1             29.1           29.0      .5020E+01     107.06    .077
 5 REG-2             14.8           14.7      .8192E+03      54.50   1.941
 6 REG-3             25.4           25.3      .1205E+02      93.52    .137


            VAR=TSS       METHOD= 4 REG-1
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       367  23  23 100.0         .271         .553       -.205   .085
***       367  23  23 100.0         .271         .553

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .271 HM3/YR
 TOTAL FLOW VOLUME =        .27 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040320 TO 20040928

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD         4360.4         4339.6      .1470E+07   16041.38    .279
 2 Q WTD C         2131.8         2121.6      .2372E+06    7842.61    .230
 3 IJC             2079.7         2069.8      .2352E+06    7650.95    .234
 4 REG-1           2469.3         2457.6      .2404E+06    9084.35    .200
 6 REG-3           2318.6         2307.6      .2293E+06    8529.97    .208
```

Blacktail Dam Outlet 385241 Flux Load Analysis

VAR=NH3-4 METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	368	12	12	100.0	1.192	3.832	-.165	.522
***	368	12	12	100.0	1.192	3.832		

FLOW STATISTICS
FLOW DURATION = 368.0 DAYS = 1.008 YEARS
MEAN FLOW RATE = 1.192 HM3/YR
TOTAL FLOW VOLUME = 1.20 HM3
FLOW DATE RANGE = 20031030 TO 20041030
SAMPLE DATE RANGE = 20040220 TO 20040812

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	755.8	750.1	.3749E+06	629.11	.816
2 Q WTD C	235.2	233.4	.3513E+05	195.76	.803
3 IJC	247.0	245.2	.4060E+05	205.62	.822
4 REG-1	285.1	283.0	.7020E+05	237.33	.936
5 REG-2	172.0	170.7	.4627E+05	143.15	1.260
6 REG-3	187.6	186.2	.3488E+05	156.16	1.003

VAR=NO2+NO3 METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	368	12	12	100.0	1.192	3.832	-.020	.848
***	368	12	12	100.0	1.192	3.832		

FLOW STATISTICS
FLOW DURATION = 368.0 DAYS = 1.008 YEARS
MEAN FLOW RATE = 1.192 HM3/YR
TOTAL FLOW VOLUME = 1.20 HM3
FLOW DATE RANGE = 20031030 TO 20041030
SAMPLE DATE RANGE = 20040220 TO 20040812

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	181.9	180.5	.1782E+04	151.39	.234
2 Q WTD C	56.6	56.2	.1958E+03	47.11	.249
3 IJC	55.5	55.1	.1923E+03	46.22	.252
4 REG-1	57.9	57.5	.3323E+03	48.23	.317
5 REG-2	54.7	54.3	.5876E+03	45.55	.446
6 REG-3	67.6	67.1	.3772E+03	56.26	.289

Blacktail Dam Outlet 385241 Flux Load Analysis (con't)

```
            VAR=T-N       METHOD= 6 REG-3
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       368  12  12 100.0        1.192        3.832       -.016   .725
***       368  12  12 100.0        1.192        3.832

 FLOW STATISTICS
 FLOW DURATION =     368.0 DAYS  =  1.008 YEARS
 MEAN FLOW RATE =     1.192 HM3/YR
 TOTAL FLOW VOLUME =       1.20 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040220 TO 20040812

 METHOD          MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD          4736.6         4701.2      .1553E+07    3942.85    .265
 2 Q WTD C          1473.9         1462.9      .4944E+05    1226.89    .152
 3 IJC              1484.4         1473.3      .5687E+05    1235.64    .162
 4 REG-1            1502.5         1491.2      .7592E+05    1250.68    .185
 5 REG-2            1434.3         1423.6      .1326E+06    1193.93    .256
 6 REG-3            1419.5         1408.9      .2714E+05    1181.64    .117


            VAR=TD-P      METHOD= 6 REG-3
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       368  12  12 100.0        1.192        3.832       -.267   .213
***       368  12  12 100.0        1.192        3.832

 FLOW STATISTICS
 FLOW DURATION =     368.0 DAYS  =  1.008 YEARS
 MEAN FLOW RATE =     1.192 HM3/YR
 TOTAL FLOW VOLUME =       1.20 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040220 TO 20040812

 METHOD          MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD           389.0          386.1      .7243E+05     323.80    .697
 2 Q WTD C           121.0          120.1      .6493E+04     100.76    .671
 3 IJC               125.9          125.0      .7528E+04     104.81    .694
 4 REG-1             165.3          164.1      .1180E+05     137.60    .662
 5 REG-2              70.9           70.3      .4181E+04      59.00    .919
 6 REG-3             109.4          108.6      .4061E+04      91.11    .587
```

Blacktail Dam Outlet 385241 Flux Load Analysis (con't)

```
           VAR=T-P       METHOD= 6 REG-3
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       368  12  12 100.0        1.192        3.832       -.223   .162
***       368  12  12 100.0        1.192        3.832

 FLOW STATISTICS
 FLOW DURATION =     368.0 DAYS  =  1.008 YEARS
 MEAN FLOW RATE =     1.192 HM3/YR
 TOTAL FLOW VOLUME =       1.20 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040220 TO 20040812

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD          508.5          504.7      .1076E+06     423.25    .650
 2 Q WTD C          158.2          157.0      .9355E+04     131.70    .616
 3 IJC              164.1          162.9      .1085E+05     136.62    .639
 4 REG-1            205.2          203.6      .1473E+05     170.80    .596
 5 REG-2            102.1          101.3      .6109E+04      84.95    .772
 6 REG-3            119.0          118.1      .3277E+04      99.08    .485


           VAR=TSS       METHOD= 2 Q WTD C
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       368  10  10 100.0        1.192        3.788       -.114   .231
***       368  10  10 100.0        1.192        3.788

 FLOW STATISTICS
 FLOW DURATION =     368.0 DAYS  =  1.008 YEARS
 MEAN FLOW RATE =     1.192 HM3/YR
 TOTAL FLOW VOLUME =       1.20 HM3
 FLOW DATE RANGE   = 20031030 TO 20041030
 SAMPLE DATE RANGE = 20040303 TO 20040812

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD        28050.1        27840.5      .8817E+08   23349.50    .337
 2 Q WTD C         8829.1         8763.2      .3341E+07    7349.57    .209
 3 IJC             8929.5         8862.8      .3787E+07    7433.11    .220
 4 REG-1          10070.1         9994.8      .1308E+08    8382.54    .362
 5 REG-2           7209.6         7155.7      .1268E+08    6001.40    .498
 6 REG-3           9507.2         9436.2      .6365E+07    7914.03    .267
```

Appendix C
BATHTUB Model Results

CASE: Blacktail Dam Calibrated Model

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	South Trib	15.570	.270	.000E+00	.000	.017
2	1	North Inlet	56.060	.490	.000E+00	.000	.009
3	1	Ungauged	5.580	.060	.000E+00	.000	.011
4	4	Outlet	77.850	1.192	.000E+00	.000	.015
		PRECIPITATION	.595	.297	.354E-02	.200	.500
		TRIBUTARY INFLOW	77.210	.820	.000E+00	.000	.011
		***TOTAL INFLOW	77.805	1.117	.354E-02	.053	.014
		GAUGED OUTFLOW	77.850	1.192	.000E+00	.000	.015
		ADVECTIVE OUTFLOW	-.045	-.372	.115E-01	.288	8.250
		***TOTAL OUTFLOW	77.805	.820	.115E-01	.131	.011
		***EVAPORATION	.000	.297	.796E-02	.300	.000

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	-------------- CONSERV -------------- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.38	3.6274	.0	.0000	.0000	.0000

CASE: Blacktail Dam Calibrated Model

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	South Trib	27.3	37.3	.000E+00	.0	.000	101.1	1.8
2	1	North Inlet	22.0	30.1	.000E+00	.0	.000	45.0	.4
3	1	Ungauged	6.0	8.2	.000E+00	.0	.000	100.0	1.1
4	4	Outlet	157.0	214.5	.000E+00	.0	.000	131.7	2.0
		PRECIPITATION	17.8	24.4	.796E+02	100.0	.500	60.0	30.0
		TRIBUTARY INFLOW	55.3	75.6	.000E+00	.0	.000	67.5	.7
		***TOTAL INFLOW	73.2	100.0	.796E+02	100.0	.122	65.5	.9
		GAUGED OUTFLOW	93.0	127.0	.000E+00	.0	.000	78.0	1.2
		ADVECTIVE OUTFLOW	-29.0	-39.6	.700E+02	87.9	.288	78.0	643.5
		***TOTAL OUTFLOW	64.0	87.4	.700E+02	87.9	.131	78.0	.8
		***RETENTION	9.2	12.6	.150E+03	187.9	1.326	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	-------------- TOTAL P -------------- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.38	3.6274	78.0	3.1701	.3154	.1261

CASE: Blacktail Dam Calibrated Model

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	South Trib	272.9	20.3	.000E+00	.0	.000	1010.7	17.5
2	1	North Inlet	413.8	30.8	.000E+00	.0	.000	844.4	7.4
3	1	Ungauged	60.0	4.5	.000E+00	.0	.000	1000.0	10.8
4	4	Outlet	1408.5	105.0	.000E+00	.0	.000	1181.6	18.1
		PRECIPITATION	594.9	44.3	.885E+05	100.0	.500	2000.0	1000.0
		TRIBUTARY INFLOW	746.7	55.7	.000E+00	.0	.000	910.6	9.7
		***TOTAL INFLOW	1341.6	100.0	.885E+05	100.0	.222	1200.6	17.2
		GAUGED OUTFLOW	1229.0	91.6	.000E+00	.0	.000	1031.0	15.8
		ADVECTIVE OUTFLOW	-383.5	-28.6	.122E+05	13.8	.288	1031.0	8505.6
		***TOTAL OUTFLOW	845.4	63.0	.122E+05	13.8	.131	1031.0	10.9
		***RETENTION	496.1	37.0	.101E+06	113.8	.640	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
1.38	3.6274	1031.0	2.2859	.4375	.3698

CASE: Blacktail Dam Calibrated Model

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Blacktail Dam

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	78.00	78.11	70.6	70.7
TOTAL N MG/M3	1031.00	1033.51	51.8	51.9
C.NUTRIENT MG/M3	53.46	53.58	69.3	69.4
CHL-A MG/M3	15.00	14.87	72.9	72.5
SECCHI M	2.50	2.55	86.5	87.0
ORGANIC N MG/M3	882.00	878.66	88.8	88.7
TP-ORTHO-P MG/M3	27.00	26.69	45.6	45.1
HOD-V MG/M3-DAY	.00	77.13	.0	50.1
MOD-V MG/M3-DAY	.00	79.31	.0	58.6
ANTILOG PC-1	337.13	332.63	59.6	59.2
ANTILOG PC-2	15.93	16.01	95.8	95.9
(N - 150) / P	11.29	11.31	27.4	27.5
INORGANIC N / P	2.92	3.01	1.0	1.1
TURBIDITY 1/M	.08	.08	1.1	1.1
ZMIX * TURBIDITY	.32	.32	.2	.2
ZMIX / SECCHI	1.60	1.57	3.0	2.8
CHL-A * SECCHI	37.50	37.85	96.7	96.8
CHL-A / TOTAL P	.19	.19	48.8	48.2
FREQ(CHL-a>10) %	63.46	62.94	.0	.0
FREQ(CHL-a>20) %	21.94	21.53	.0	.0
FREQ(CHL-a>30) %	7.66	7.47	.0	.0
FREQ(CHL-a>40) %	2.92	2.83	.0	.0
FREQ(CHL-a>50) %	1.22	1.17	.0	.0
FREQ(CHL-a>60) %	.55	.52	.0	.0
CARLSON TSI-P	66.97	66.99	.0	.0
CARLSON TSI-CHLA	57.17	57.08	.0	.0
CARLSON TSI-SEC	46.80	46.54	.0	.0

CASE: Blacktail Dam Calibrated With 25% Nutrient Reduction

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	South Trib	15.570	.270	.000E+00	.000	.017
2	1	North Inlet	56.060	.490	.000E+00	.000	.009
3	1	Ungauged	5.580	.060	.000E+00	.000	.011
4	4	Outlet	77.850	1.192	.000E+00	.000	.015
		PRECIPITATION	.595	.297	.354E-02	.200	.500
		TRIBUTARY INFLOW	77.210	.820	.000E+00	.000	.011
		***TOTAL INFLOW	77.805	1.117	.354E-02	.053	.014
		GAUGED OUTFLOW	77.850	1.192	.000E+00	.000	.015
		ADVECTIVE OUTFLOW	-.045	-.372	.115E-01	.288	8.250
		***TOTAL OUTFLOW	77.805	.820	.115E-01	.131	.011
		***EVAPORATION	.000	.297	.796E-02	.300	.000

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	CONSERV POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.38	3.6274	.0	.0000	.0000	.0000

CASE: Blacktail Dam Calibrated With 25% Nutrient Reduction

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	South Trib	20.5	34.5	.000E+00	.0	.000	75.8	1.3
2	1	North Inlet	16.5	27.9	.000E+00	.0	.000	33.7	.3
3	1	Ungauged	4.5	7.6	.000E+00	.0	.000	75.0	.8
4	4	Outlet	157.0	264.5	.000E+00	.0	.000	131.7	2.0
		PRECIPITATION	17.8	30.1	.796E+02	100.0	.500	60.0	30.0
		TRIBUTARY INFLOW	41.5	69.9	.000E+00	.0	.000	50.6	.5
		***TOTAL INFLOW	59.4	100.0	.796E+02	100.0	.150	53.1	.8
		GAUGED OUTFLOW	93.0	156.6	.000E+00	.0	.000	78.0	1.2
		ADVECTIVE OUTFLOW	-29.0	-48.9	.700E+02	87.9	.288	78.0	643.5
		***TOTAL OUTFLOW	64.0	107.8	.700E+02	87.9	.131	78.0	.8
		***RETENTION	-4.6	-7.8	.150E+03	187.9	2.655	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.38	3.6274	78.0	3.9090	.2558	-.0776

CASE: Blacktail Dam Calibrated With 25% Nutrient Reduction

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	South Trib	204.7	17.7	.000E+00	.0	.000	758.0	13.1
2	1	North Inlet	310.3	26.9	.000E+00	.0	.000	633.3	5.5
3	1	Ungauged	45.0	3.9	.000E+00	.0	.000	750.0	8.1
4	4	Outlet	1408.5	122.0	.000E+00	.0	.000	1181.6	18.1
		PRECIPITATION	594.9	51.5	.885E+05	100.0	.500	2000.0	1000.0
		TRIBUTARY INFLOW	560.0	48.5	.000E+00	.0	.000	682.9	7.3
		***TOTAL INFLOW	1154.9	100.0	.885E+05	100.0	.258	1033.5	14.8
		GAUGED OUTFLOW	1229.0	106.4	.000E+00	.0	.000	1031.0	15.8
		ADVECTIVE OUTFLOW	-383.5	-33.2	.122E+05	13.8	.288	1031.0	8505.6
		***TOTAL OUTFLOW	845.4	73.2	.122E+05	13.8	.131	1031.0	10.9
		***RETENTION	309.5	26.8	.101E+06	113.8	1.025	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
1.38	3.6274	1031.0	2.6554	.3766	.2680

CASE: Blacktail Dam Calibrated With 25% Nutrient Reduction

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Blacktail Dam

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	78.00	63.34	70.6	62.2
TOTAL N MG/M3	1031.00	889.70	51.8	42.6
C.NUTRIENT MG/M3	53.46	44.18	69.3	60.5
CHL-A MG/M3	15.00	12.06	72.9	62.7
SECCHI M	2.50	3.01	86.5	91.2
ORGANIC N MG/M3	882.00	766.51	88.8	82.7
TP-ORTHO-P MG/M3	27.00	21.19	45.6	35.7
HOD-V MG/M3-DAY	.00	69.46	.0	44.5
MOD-V MG/M3-DAY	.00	71.43	.0	52.8
ANTILOG PC-1	337.13	232.61	59.6	48.4
ANTILOG PC-2	15.93	15.81	95.8	95.6
(N - 150) / P	11.29	11.68	27.4	29.1
INORGANIC N / P	2.92	2.92	1.0	1.0
TURBIDITY 1/M	.08	.08	1.1	1.1
ZMIX * TURBIDITY	.32	.32	.2	.2
ZMIX / SECCHI	1.60	1.33	3.0	1.4
CHL-A * SECCHI	37.50	36.35	96.7	96.4
CHL-A / TOTAL P	.19	.19	48.8	48.2
FREQ(CHL-a>10) %	63.46	49.68	.0	.0
FREQ(CHL-a>20) %	21.94	13.01	.0	.0
FREQ(CHL-a>30) %	7.66	3.76	.0	.0
FREQ(CHL-a>40) %	2.92	1.24	.0	.0
FREQ(CHL-a>50) %	1.22	.46	.0	.0
FREQ(CHL-a>60) %	.55	.19	.0	.0
CARLSON TSI-P	66.97	63.97	.0	.0
CARLSON TSI-CHLA	57.17	55.03	.0	.0
CARLSON TSI-SEC	46.80	44.10	.0	.0

CASE: Blacktail Dam Calibrated with 50% Reduction

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	South Trib	15.570	.270	.000E+00	.000	.017
2	1	North Inlet	56.060	.490	.000E+00	.000	.009
3	1	Ungauged	5.580	.060	.000E+00	.000	.011
4	4	Outlet	77.850	1.192	.000E+00	.000	.015
		PRECIPITATION	.595	.297	.354E-02	.200	.500
		TRIBUTARY INFLOW	77.210	.820	.000E+00	.000	.011
		***TOTAL INFLOW	77.805	1.117	.354E-02	.053	.014
		GAUGED OUTFLOW	77.850	1.192	.000E+00	.000	.015
		ADVECTIVE OUTFLOW	-.045	-.372	.115E-01	.288	8.250
		***TOTAL OUTFLOW	77.805	.820	.115E-01	.131	.011
		***EVAPORATION	.000	.297	.796E-02	.300	.000

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	CONSERV POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.38	3.6274	.0	.0000	.0000	.0000

CASE: Blacktail Dam Calibrated With 50% Nutrient Reduction

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	South Trib	13.5	29.8	.000E+00	.0	.000	50.0	.9
2	1	North Inlet	10.9	24.1	.000E+00	.0	.000	22.3	.2
3	1	Ungauged	3.0	6.6	.000E+00	.0	.000	50.0	.5
4	4	Outlet	157.0	346.7	.000E+00	.0	.000	131.7	2.0
		PRECIPITATION	17.8	39.4	.796E+02	100.0	.500	60.0	30.0
		TRIBUTARY INFLOW	27.4	60.6	.000E+00	.0	.000	33.5	.4
		***TOTAL INFLOW	45.3	100.0	.796E+02	100.0	.197	40.5	.6
		GAUGED OUTFLOW	93.0	205.3	.000E+00	.0	.000	78.0	1.2
		ADVECTIVE OUTFLOW	-29.0	-64.1	.700E+02	87.9	.288	78.0	643.5
		***TOTAL OUTFLOW	64.0	141.3	.700E+02	87.9	.131	78.0	.8
		***RETENTION	-18.7	-41.3	.150E+03	187.9	.655	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.38	3.6274	78.0	5.1242	.1952	-.4126

CASE: Blacktail Dam Calibrated With 50% Nutrient Reduction

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL N

			LOADING		VARIANCE			CONC	EXPORT
ID	T	LOCATION	KG/YR	%(I)	KG/YR**2	%(I)	CV	MG/M3	KG/KM2
1	1	South Trib	135.1	14.0	.000E+00	.0	.000	500.3	8.7
2	1	North Inlet	204.8	21.2	.000E+00	.0	.000	418.0	3.7
3	1	Ungauged	30.0	3.1	.000E+00	.0	.000	500.0	5.4
4	4	Outlet	1408.5	146.0	.000E+00	.0	.000	1181.6	18.1
		PRECIPITATION	594.9	61.7	.885E+05	100.0	.500	2000.0	1000.0
		TRIBUTARY INFLOW	369.9	38.3	.000E+00	.0	.000	451.1	4.8
		***TOTAL INFLOW	964.8	100.0	.885E+05	100.0	.308	863.4	12.4
		GAUGED OUTFLOW	1229.0	127.4	.000E+00	.0	.000	1031.0	15.8
		ADVECTIVE OUTFLOW	-383.5	-39.8	.122E+05	13.8	.288	1031.0	8505.6
		***TOTAL OUTFLOW	845.4	87.6	.122E+05	13.8	.131	1031.0	10.9
		***RETENTION	119.4	12.4	.101E+06	113.8	2.658	.0	.0

	HYDRAULIC	TOTAL N			
OVERFLOW RATE	RESIDENCE TIME	POOL CONC	RESIDENCE TIME	TURNOVER RATIO	RETENTION COEF
M/YR	YRS	MG/M3	YRS	-	-
1.38	3.6274	1031.0	3.1786	.3146	.1237

CASE: Blacktail Dam Calibrated With 50% Nutrient Reduction

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Blacktail Dam

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	78.00	48.32	70.6	50.4
TOTAL N MG/M3	1031.00	743.26	51.8	32.0
C.NUTRIENT MG/M3	53.46	34.56	69.3	48.4
CHL-A MG/M3	15.00	9.20	72.9	48.9
SECCHI M	2.50	3.71	86.5	94.8
ORGANIC N MG/M3	882.00	652.38	88.8	73.4
TP-ORTHO-P MG/M3	27.00	15.59	45.6	24.5
HOD-V MG/M3-DAY	.00	60.66	.0	37.4
MOD-V MG/M3-DAY	.00	62.38	.0	45.2
ANTILOG PC-1	337.13	148.41	59.6	35.1
ANTILOG PC-2	15.93	15.47	95.8	95.2
(N - 150) / P	11.29	12.28	27.4	31.6
INORGANIC N / P	2.92	2.78	1.0	.9
TURBIDITY 1/M	.08	.08	1.1	1.1
ZMIX * TURBIDITY	.32	.32	.2	.2
ZMIX / SECCHI	1.60	1.08	3.0	.5
CHL-A * SECCHI	37.50	34.13	96.7	95.6
CHL-A / TOTAL P	.19	.19	48.8	48.2
FREQ(CHL-a>10) %	63.46	32.83	.0	.0
FREQ(CHL-a>20) %	21.94	5.91	.0	.0
FREQ(CHL-a>30) %	7.66	1.33	.0	.0
FREQ(CHL-a>40) %	2.92	.37	.0	.0
FREQ(CHL-a>50) %	1.22	.12	.0	.0
FREQ(CHL-a>60) %	.55	.04	.0	.0
CARLSON TSI-P	66.97	60.07	.0	.0
CARLSON TSI-CHLA	57.17	52.37	.0	.0
CARLSON TSI-SEC	46.80	41.11	.0	.0

CASE: Blacktail Dam Calibrated With 75% Nutrient Reduction

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	South Trib	15.570	.270	.000E+00	.000	.017
2	1	North Inlet	56.060	.490	.000E+00	.000	.009
3	1	Ungauged	5.580	.060	.000E+00	.000	.011
4	4	Outlet	77.850	1.192	.000E+00	.000	.015
		PRECIPITATION	.595	.297	.354E-02	.200	.500
		TRIBUTARY INFLOW	77.210	.820	.000E+00	.000	.011
		***TOTAL INFLOW	77.805	1.117	.354E-02	.053	.014
		GAUGED OUTFLOW	77.850	1.192	.000E+00	.000	.015
		ADVECTIVE OUTFLOW	-.045	-.372	.115E-01	.288	8.250
		***TOTAL OUTFLOW	77.805	.820	.115E-01	.131	.011
		***EVAPORATION	.000	.297	.796E-02	.300	.000

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	CONSERV POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.38	3.6274	.0	.0000	.0000	.0000

CASE: Blacktail Dam Calibrated With 75% Nutrient Reduction

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	South Trib	7.3	22.7	.000E+00	.0	.000	27.0	.5
2	1	North Inlet	5.5	17.0	.000E+00	.0	.000	11.1	.1
3	1	Ungauged	1.5	4.7	.000E+00	.0	.000	25.0	.3
4	4	Outlet	157.0	489.0	.000E+00	.0	.000	131.7	2.0
		PRECIPITATION	17.8	55.6	.796E+02	100.0	.500	60.0	30.0
		TRIBUTARY INFLOW	14.3	44.4	.000E+00	.0	.000	17.4	.2
		***TOTAL INFLOW	32.1	100.0	.796E+02	100.0	.278	28.7	.4
		GAUGED OUTFLOW	93.0	289.6	.000E+00	.0	.000	78.0	1.2
		ADVECTIVE OUTFLOW	-29.0	-90.4	.700E+02	87.9	.288	78.0	643.5
		***TOTAL OUTFLOW	64.0	199.2	.700E+02	87.9	.131	78.0	.8
		***RETENTION	-31.9	-99.2	.150E+03	187.9	.384	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.38	3.6274	78.0	7.2269	.1384	-.9923

CASE: Blacktail Dam Calibrated With 75% Nutrient Reduction

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	South Trib	67.5	8.7	.000E+00	.0	.000	250.0	4.3
2	1	North Inlet	102.4	13.1	.000E+00	.0	.000	209.0	1.8
3	1	Ungauged	15.0	1.9	.000E+00	.0	.000	250.0	2.7
4	4	Outlet	1408.5	180.6	.000E+00	.0	.000	1181.6	18.1
PRECIPITATION			594.9	76.3	.885E+05	100.0	.500	2000.0	1000.0
TRIBUTARY INFLOW			184.9	23.7	.000E+00	.0	.000	225.5	2.4
***TOTAL INFLOW			779.8	100.0	.885E+05	100.0	.381	697.8	10.0
GAUGED OUTFLOW			1229.0	157.6	.000E+00	.0	.000	1031.0	15.8
ADVECTIVE OUTFLOW			-383.5	-49.2	.122E+05	13.8	.288	1031.0	8505.6
***TOTAL OUTFLOW			845.4	108.4	.122E+05	13.8	.131	1031.0	10.9
***RETENTION			-65.6	-8.4	.101E+06	113.8	4.837	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
1.38	3.6274	1031.0	3.9326	.2543	-.0841

CASE: Blacktail Dam Calibrated With 75% Nutrient Reduction

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Blacktail Dam

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	78.00	34.26	70.6	35.5
TOTAL N MG/M3	1031.00	600.74	51.8	21.2
C.NUTRIENT MG/M3	53.46	25.31	69.3	33.4
CHL-A MG/M3	15.00	6.52	72.9	31.8
SECCHI M	2.50	4.73	86.5	97.4
ORGANIC N MG/M3	882.00	545.58	88.8	60.9
TP-ORTHO-P MG/M3	27.00	10.35	45.6	13.1
HOD-V MG/M3-DAY	.00	51.08	.0	29.1
MOD-V MG/M3-DAY	.00	52.53	.0	35.8
ANTILOG PC-1	337.13	85.50	59.6	21.1
ANTILOG PC-2	15.93	14.90	95.8	94.5
(N - 150) / P	11.29	13.16	27.4	35.3
INORGANIC N / P	2.92	2.31	1.0	.5
TURBIDITY 1/M	.08	.08	1.1	1.1
ZMIX * TURBIDITY	.32	.32	.2	.2
ZMIX / SECCHI	1.60	.85	3.0	.1
CHL-A * SECCHI	37.50	30.86	96.7	94.1
CHL-A / TOTAL P	.19	.19	48.8	48.2
FREQ(CHL-a>10) %	63.46	15.89	.0	.0
FREQ(CHL-a>20) %	21.94	1.71	.0	.0
FREQ(CHL-a>30) %	7.66	.28	.0	.0
FREQ(CHL-a>40) %	2.92	.06	.0	.0
FREQ(CHL-a>50) %	1.22	.02	.0	.0
FREQ(CHL-a>60) %	.55	.01	.0	.0
CARLSON TSI-P	66.97	55.11	.0	.0
CARLSON TSI-CHLA	57.17	49.00	.0	.0
CARLSON TSI-SEC	46.80	37.61	.0	.0

Appendix D
A Calibrated Trophic Response Model (BATHTUB) for Blacktail Dam as a Tool to Evaluate Various Nutrient Reduction Alternatives

Based on Data Collected by the Williams County Soil Conservation District from June 20, 2003 through October 31, 2004

Prepared by
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November 6, 2004
Updated June 23, 2006

Introduction

In order to meet the project goals, as set forth by the project sponsors of identifying possible options to improve the trophic condition of Blacktail Dam to levels capable of maintaining the reservoirs beneficial uses (e.g., fishing, recreation, and drinking water supply), and the objectives of this project, which are to: (1) develop a nutrient and sediment budget for the reservoir; (2) identify the primary sources and causes of nutrients and sediments to the reservoir; and (3) examine and make recommendations for reservoir restoration measures which will reduce documented nutrient and sediment loadings to the reservoir, a calibrated trophic response model was developed for Blacktail Dam. The model enables investigations into various nutrient reduction alternatives relative to the project goal of improving Blacktail Dam's trophic status. The model will allow resource managers and the public to relate changes in nutrient loadings to the trophic condition of the reservoir and to set realistic lake restoration goals that are scientifically defensible, achievable and socially acceptable.

Methods

For purposes of this project, the BATHTUB program was use to predict changes in trophic status based on changes in nutrient loading. The BATHTUB program, developed by the US Army Corps of Engineers Waterways Experiment Station (Walker 1996), applies an empirically derived eutrophication model to reservoirs. The model is developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data. The third phase involves model calibration. In the data reduction phase, the in-lake and tributary monitoring data collected as part of the project are summarized, or reduced, in a format which can serve as inputs to the model. The following is a brief explanation of the computer software, methods, and procedures used to complete each of these phases.

Tributary Data

To facilitate the analysis and reduction of tributary inflow and outflow water quality and flow data the FLUX program was employed. The FLUX program, also developed by the US Corps of Engineers Waterways Experiment Station (Walker 1996), uses six calculation techniques to estimate the average mass discharge or loading that passes a given river or stream site. FLUX estimates loadings based on grab sample chemical concentrations and continuous daily flow record. Load is therefore defined as the mass of a pollutant during a given time period (e.g., hour, day, month, season, year). The FLUX program allows the user, through various iterations, to select the most appropriate load calculation technique and data stratification scheme, either by flow or date, which will give a load estimate with the smallest statistical error, as represented by the coefficient of variation. Output from the FLUX program is then provided as an input file to calibrate the BATHTUB eutrophication response model. For a complete description of the FLUX program the reader is referred to Walker (1996).

Lake Data

Blacktail Dam's in-lake water quality data was reduced using Microsoft Excel. The data was reduced in excel to provide three computational functions, including: (1) the ability to display constitute concentrations as a function of depth, location, and/or date; (2) calculate summary statistics (e.g., mean, median and standard error in the mixed layer of the lake or reservoir); and (3) track the temporal trophic status. As is the case with FLUX, output from the Excel program is used as input to calibrate the BATHTUB model.

Bathtub Model Calibration

As stated previously, the BATHTUB eutrophication model was selected for this project as a means of evaluating the effects of various nutrient reduction alternatives on the predicted trophic status of Blacktail Dam. BATHTUB performs water and nutrient balance calculations in a steady-state. The BATHTUB model also allows the user to spatially segment the reservoir. Eutrophication related water quality variables (e.g., total phosphorus, total nitrogen, chlorophyll-*a*, secchi depth, organic nitrogen, orthophosphorous, and hypolimnetic oxygen depletion rate) are predicted using empirical relationships previously developed and tested for reservoir systems (Walker 1985).

Within the BATHTUB program the user can select from six schemes based on reservoir morphometry and the needs of the resource manager. Using BATHTUB the user can view the reservoir as a single spatially averaged reservoir or as single segmented reservoir. The user can also model parts of the reservoir, such as an embayment, or model a collection of reservoirs. For purposes of this project, Blacktail Dam was modeled as a single, spatially averaged, reservoir.

Once input is provided to the model from FLUX and Excel the user can compare predicted conditions (i.e., model output) to actual conditions. Since BATHTUB uses a set of generalized rates and factors, predicted vs. actual conditions may differ by a factor of 2 or more using the initial, un-calibrated, model. These differences reflect a combination of measurement errors in the inflow and outflow data, as well as unique features of the reservoir being modeled.

In order to closely match an actual in-lake condition with the predicted condition, BATHTUB allows the user to modify a set of calibration factors (Table 1). For a complete description of the BATHTUB model the reader is referred to Walker (1996).

Table 1. Selected model parameters, number and name of model, and where appropriate the calibration factor used for Blacktail Dam Bathtub Model.

Model Option	Model Selection	Calibration Factor
Conservative Substance	1 Computed	1.00
Phosphorus Balance	7 Settling Velocity	1.51
Phosphorus – Ortho P	7	1.10
Nitrogen Balance	7 Settling Velocity	1.09
Organic Nitrogen	7	1.75
Chlorophyll-a	4 P Linear	0.68
Secchi Depth	1 Vs. Chla & Turbidity	1.15
Phosphorus Calibration	2 Concentrations	NA
Nitrogen Calibration	2 Concentrations	NA
Availability Factors	0 Ignore	NA
Mass-Balance Tables	0 Use Observed Concentrations	NA

Results

The trophic response model, BATHTUB, has been calibrated to match Blacktail Dam's trophic response for the project period between June 20, 2003 through October 31, 2004. This is accomplished by combining tributary loading estimates for the hydrologic year October 31, 2003 through October 31, 2004 with in-lake water quality. Tributary flow and concentration data for the project period are reduced by the FLUX program and the corresponding in-lake water quality data are reduced utilizing Excel. The output from these two programs is then provided as input to the BATHTUB model. The model is calibrated through several iterations, first by selecting appropriate empirical relationships for model coefficients (e.g., nitrogen and phosphorus sedimentation, nitrogen and phosphorus decay, oxygen depletion, and algal/chlorophyll growth), and second by adjusting model calibration factors for those coefficients (Table 1). The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates made from project monitoring data.

The two most important nutrients controlling trophic response in Blacktail Dam are nitrogen and phosphorus. After calibration the observed average annual concentration of total nitrogen and total phosphorus compare well with those of the BATHTUB model. The model predicts that the reservoir has an annual volume weighted average total phosphorus concentration of 0.078 mg L^{-1} and an annual average volume weighted total nitrogen concentration of 1.034 mg L^{-1} compared to observed values for total phosphorus and total nitrogen of 0.077 mg L^{-1} and 1.031 mg L^{-1}, respectively (Table 2).

Other measures of trophic response predicted by the model are average annual chlorophyll-a concentration and average secchi disk transparency. The calibrated model did just as good a job of predicting average chlorophyll-a concentration and secchi disk transparency within the reservoir as total phosphorus and total nitrogen (Table 2).

Once predictions of total phosphorus, chlorophyll-a, and secchi disk transparency are made, the model calculates Carlson's Trophic Status Index (TSI) (Carlson 1977) as a means of expressing predicted trophic response (Table 2). Carlson's TSI is an index that can be used to measure the relative trophic state of a lake or reservoir. Simply stated, trophic state is how much production (i.e., algal and weed growth) occurs in the waterbody. The lower the nutrient concentrations are within the waterbody the lower the production and the lower the trophic state or level. In contrast, increased nutrient concentrations in a lake or reservoir increase the production of algae and weeds which make the lake or reservoir more eutrophic or of a higher trophic state. Oligotrophic is the term which describes the least productive lakes and hypereutrophic is the term used to describe lakes and reservoirs with excessive nutrients and primary production.

Table 2. Observed and Predicted Values for Selected Trophic Response Variables for the Calibrated "BATHTUB" Model.

	Value	
Variable	Observed	Predicted
Total Phosphorus as P (mg/L)	0.078	0.078
Total Dissolved Phosphorus (mg/L)	0.051	0.051
Total Nitrogen as N (mg/L)	1.032	1.033
Organic Nitrogen as N (mg/L)	0.882	0.879
Chlorophyll-a (μg/L)	15.00	14.87
Secchi Disk Transparency (meters)	2.50	2.55
Carlson's TSI for Phosphorus	66.97	66.99
Carlson's TSI for Chlorophyll-a	57.17	57.08
Carlson's TSI for Secchi Disk	46.80	46.54

Figure 1 provides a graphic summary of the TSI range for each trophic level compared to values for each of the trophic response variables. The calibrated model provided predictions of trophic status which are similar to the observed TSI values for the project period (Table 2). Over all the predicted and observed TSI values for phosphorus, chlorophyll and secchi disk suggest Blacktail Dam is eutrophic. Figure 2 is a graphic that shows the annual temporal distribution of Blacktail Dam's trophic state based on the three parameters total phosphorus as phosphate, and chlorophyll-a concentrations and secchi disk depth transparency.

Model Predictions

Once the model is calibrated to existing conditions, the model can be used to evaluate the effectiveness of any number of nutrient reduction or lake restoration alternatives. This evaluation is accomplished comparing predicted trophic state, as reflected by Carlson's TSI, with currently observed TSI values. Modeled nutrient reduction alternatives are presented in three basic categories: (1) reducing externally derived nutrient loads; (2) reducing internally available nutrients; and (3) reducing both external and internal nutrient loads. For Blacktail Dam only external nutrient loads were addressed. External nutrient loads were addressed because they are known to cause eutrophication and because they are controllable through the implementation of watershed Best Management Practices (BMPs).

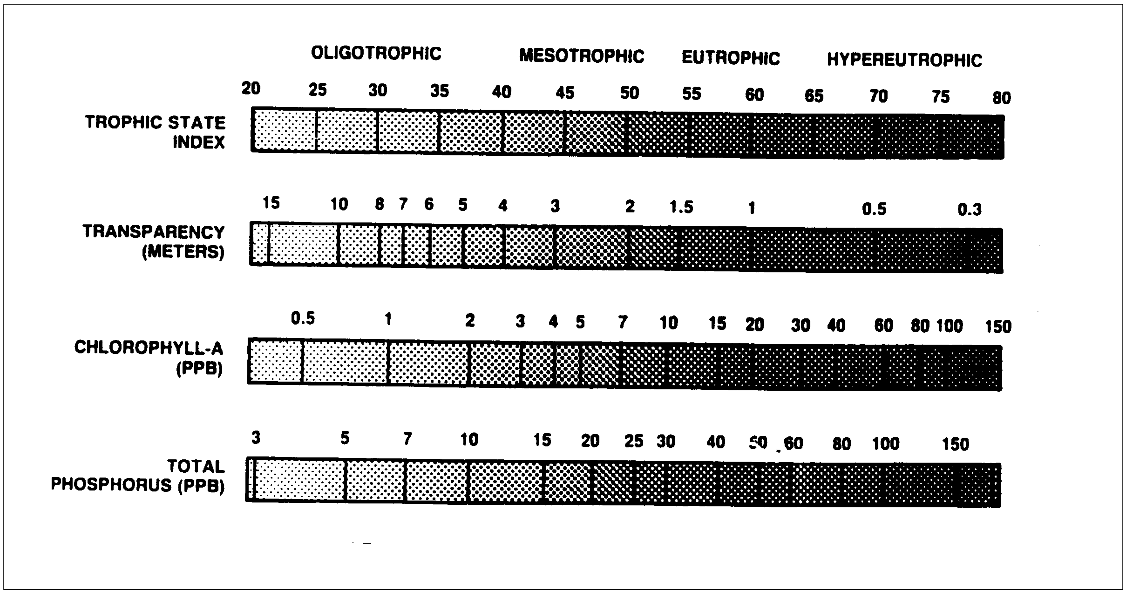

Figure 1. Graphic depiction of Carlson's Trophic Status Index.

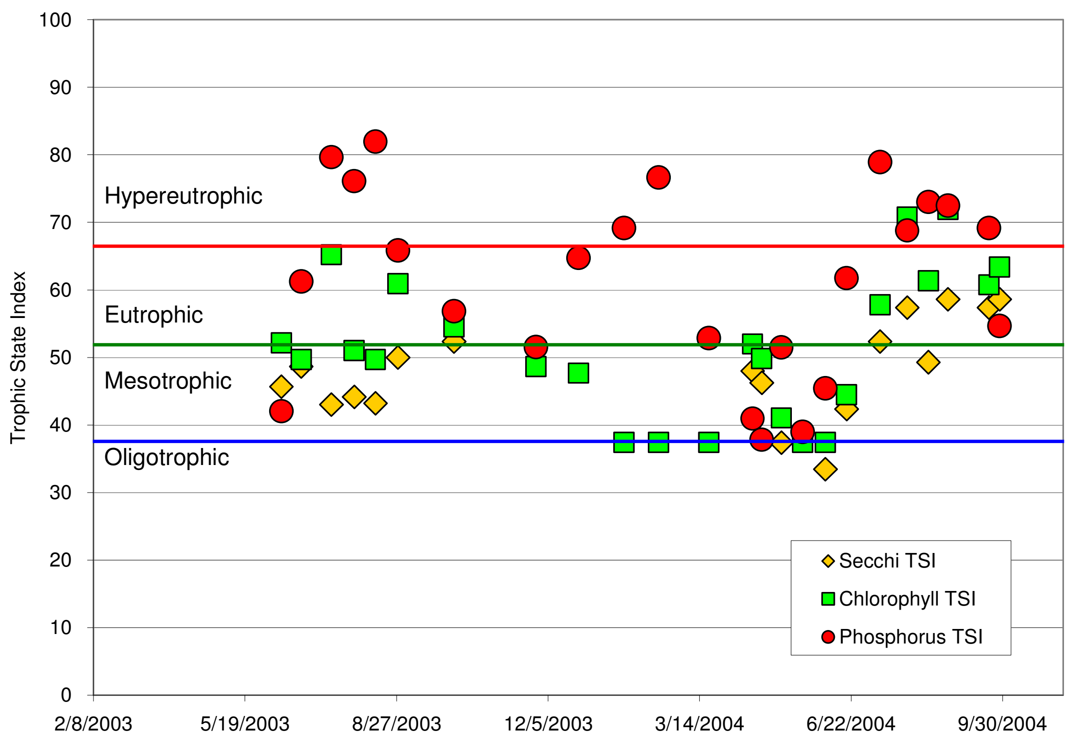

Figure 2. Temporal distribution of Carlosn's Trophic Status Index scores for Blacktail Dam (12-17-2002 though 10-19-2003).

Predicted changes in trophic response to Blacktail Dam were evaluated by reducing externally derived phosphorus loads by 25, 50, and 75 percent. These reductions were simulated in the model by reducing the phosphorus concentrations in the contributing tributary and other external delivery sources by 25, 50, and 75 percent. Since there is no reliable means of estimating how much hydraulic discharge would be reduced through the implementation of BMPs, flow was held constant.

The model results indicate that if it were possible to reduce external phosphorus loading to Blacktail Dam by 50 percent the average annual total phosphorus and chlorophyll-a concentrations in the lake would decrease as well and secchi disk transparency depth would increase significantly (Table 3, Figure 3). With a 50 percent reduction in external phosphorus and nitrogen load, the model predicts a reduction in Carlson's TSI score from 47 to 39 for chlorophyll-a and from 57 to 52 for secchi disk transparency, corresponding to a trophic state of oligotrohic and mesotrophic, respectively.

Table 3. Observed and Predicted Values for Selected Trophic Response Variables Assuming a 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading.

		Predicted		
Variable	Observed	25 %	50 %	75 %
Total Phosphorus as P (mg/L)	0.078	0.063	0.048	0.034
Total Dissolved Phosphorus (mg/L)	0.027	0.042	0.036	0.024
Total Nitrogen as N (mg/L)	1.031	0.890	0.743	0.601
Organic Nitrogen as N (mg/L)	0.882	0.767	0.652	0.546
Chlorophyll-a (μg/L)	15.00	12.06	9.20	6.52
Secchi Disk Transparency (meters)	2.50	3.01	3.71	4.73
Carlson's TSI for Phosphorus	66.97	63.97	60.07	55.11
Carlson's TSI for Chlorophyll-a	57.17	55.03	52.37	49.00
Carlson's TSI for Secchi Disk	46.80	44.10	41.11	37.61

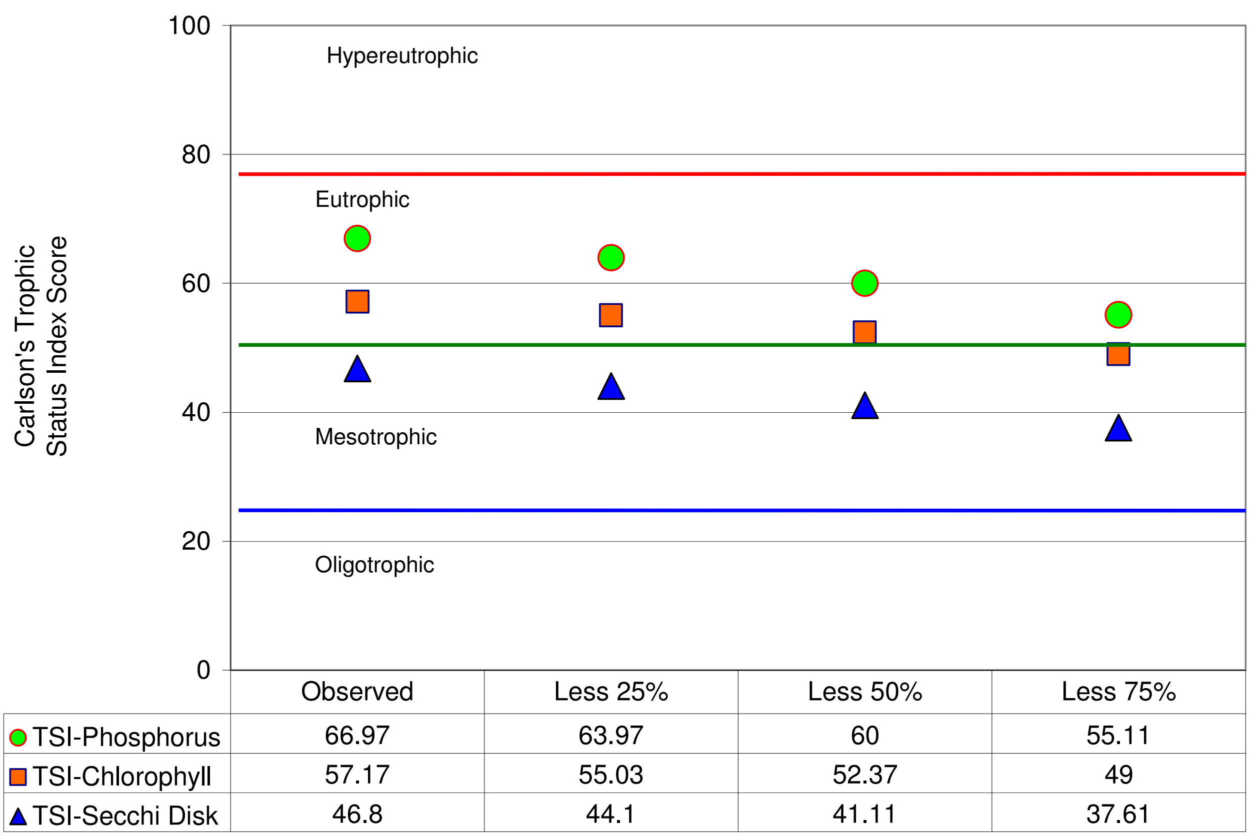

Figure 3. Predicted trophic response to phosphorus load reductions to Blacktail Dam of 25, 50, and 75 percent.

Appendix E

US Fish and Wildlife Service List of Threatened and Endangered Species and Designated Critical Habitat in Williams County, North Dakota

FEDERAL THREATENED AND ENDANGERED SPECIES
AND DESIGNATED CRITICAL HABITAT FOUND IN
WILLIAMS COUNTY, NORTH DAKOTA
May 2006

ENDANGERED SPECIES

Birds

Interior least tern (Sterna antillarum): Nests along midstream sandbars of the Missouri and Yellowstone Rivers.

Whooping crane (Grus Americana): Migrates through west and central counties during spring and fall. Prefers to roost on wetlands and stockdams with good visibility. Young adult summered in North Dakota in 1989, 1990, and 1993. Total population 140-150 birds.

Fish

Pallid sturgeon (Scaphirhynchus albus): Known only from the Missouri and Yellowstone Rivers. No reproduction has been documented in 15 years.

Mammals

Gray wolf (Canis lupus): Occasional visitor in North Dakota. Most frequently observed in the Turtle Mountains area.

THREATENED SPECIES

Birds

Bald eagle (Haliaeetus leucocephalus): Migrates spring and fall statewide but primarily along the major river courses. It concentrates along the Missouri River during winter and is known to nest in the floodplain forest.

Piping plover (Charadrius melodus): Nests on midstream sandbars of the Missouri and Yellowstone Rivers and along shorelines of saline wetlands. More nest in North Dakota than any other state.

Appendix F

Department Response to Comments

During the 30 day public notice soliciting comment and participation for the Blacktail Dam Nutrient and Dissolved Oxygen TMDL, the North Dakota Department of Health received an email from Mr. Fred Ryckman with the North Dakota Game and Fish Department on January 3, 2008. Below are the comments provided and the departments' response.

Comment from NDGF: "I'd encourage that a better map be developed and included within the report as Figure 13; perhaps an aerial photo with the 40 acre grid lines and critical areas designed by some type of shading. I think a better map would help to visualize the problem areas?"

NDDoH Response: The AGNPS modeling software does not allow for the integration of the output map with an aerial photo map. Information is available in the output files as to the location of identified critical cells. In the event a watershed implementation project is initiated this information will be made available to the watershed coordinator. The Department will also require that these areas be the focus of any watershed implementation project.

Comment from NDGF: "I'd strongly urge that more information be provided on the two identified feedlots within the watershed; as written the report has no information at all on these feedlots. Their location should be noted on the map in Figure 13, and at least a brief description of the number of livestock, proximity to waterways, etc. should be included within the text. This information is badly needed so that a better assessment can be made regarding the impact of these feedlots on the lake."

NDDoH Response: While not specifically identified on the map in Figure 13, these two feedlots are included in the model input file. Therefore, the locations of these feedlots are known to the Department and to the Williams County SCD. In the event a watershed implementation project is initiated this information will be made available to the watershed coordinator. The Department will also require that these areas be the focus of any watershed implementation project.

Comment from NDGF: "although the draft report contains a fairly good explanation of the process for assessing water quality inputs associated with Blacktail's cabins' septic systems, I think it would be good to at least reference that additional information should be collected regarding the impacts of the cabin users on the lake. If there are a number of deficient or faulty septic systems, perhaps the targeted nutrient reduction could be more practically obtained by addressing this issue rather than land use away from the lake?"

NDDoH Response: Additional language has been added to Section 8.0, Allocation, which identifies the need to do additional study on the condition and extent of failing septic systems as part of any watershed implementation project.